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One Stop To Orbit
by Robert M. Zubrin &
Mitchell Burnside Clapp

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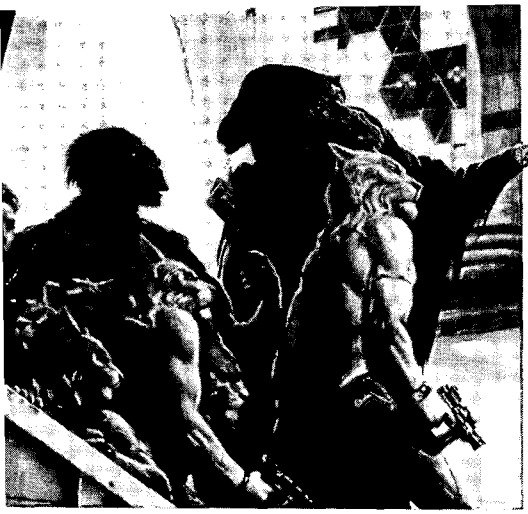

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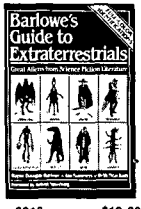

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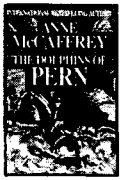

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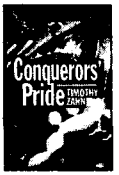

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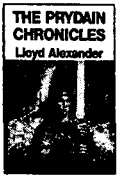

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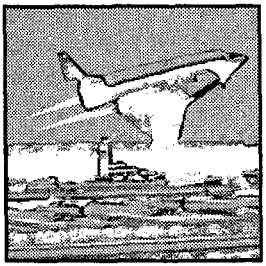

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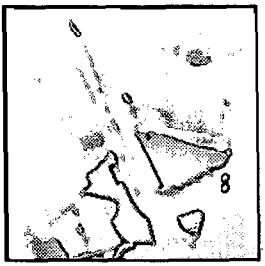

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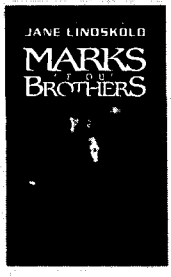

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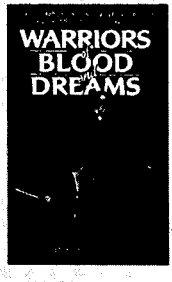

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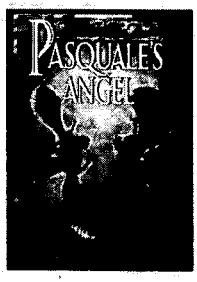

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GUEST EDITORIAL G. Harry Stine

WHY BUILD EXPERIMENTAL VEHICLES?

(Author's Note: On July 19, 1994, I was asked to testify before the House Committee on Science, Space, and Technology concerning the need and advisability of building and flying experimental spaceships such as the McDonnell Douglas DC-X and SX-2. Some science and technology advisors and committee staff members in Washington, in addition to some managers in NASA, were convinced that the only way to do the job was to spend dirksens (dirksen = a billion dollars) to study, study, study, then build the perfect single-stage-to-orbit spaceship perhaps ten years in the future once all the technology was "well understood." What follows is my viewpoint, rationale, and justification for doing it fast, cheap, and in accordance with historical practice that we *know* works. Congressional testimony usually gets buried in the deluge of words that pours from our nation's capital, but publication in this magazine reaches well over a hundred thousand readers, many of whom may profit from these observations.)

Recently, the justification for building and testing experimental aerospace vehicles ("X ships"), a procedure well-established for decades in engineering practice, has been questioned by some people who may believe that engineering and technology have progressed to the point where it's possible now to go directly from the CAD computer screen to an operational product.

In designing and building any sort of device in which people are involved and human lives may be at risk because of potential failures of the device, two approaches have come into confrontation over the past twenty-five years.

The first is the classical approach supported by centuries of engineering experience. Being very conservative, an engineer will design devices that are safe, practical, and economical (in that order of priority). Therefore, an engineer will build and test one or more experimental devices to determine (a) if the calcula-

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tions and basic technical assumptions are correct, (b) how the complex systems within the device interact in complicated and usually unanticipated ways, (c) whether or not something has been inadvertently overlooked in the design and construction process, and (d) how novel technology performs in this arrangement.

This classical approach has been extremely successful over the years. However, few people outside the engineering profession ever learn about the failures of experimental devices. No one knows (and few people care) about the failures of all the experimental automobiles, aircraft, computers, TV sets, and other technical devices that occur in a company's testing labs or proving grounds. Even computer programmers depend upon alpha and beta tests of experimental software. These tests always reveal shortcomings and failures that are corrected before the product goes to market.

Henry Petroski, professor of civil engineering at Duke University, points out in his two outstanding books, *To Engineer Is Human: The Role of Failure In Successful Design* and *The Evolution of Useful Things*, that technology progresses because of failures in previous designs and that invention involves eliminating the undesirable failures and shortcomings of an existing product or service. He writes:

"Because man is fallible, so are his constructions, however. Thus, the history of structural engineering, indeed the history of engineering in general, may be told in its failures as well as in its triumphs. Success may be grand, but disappointment can often teach us more."

Experimental devices are therefore widely used in applied technology (engineering) not to "get the technology well understood and in hand" (an impossibility given Murphy's Law and chaos theory) but to eliminate failure insofar as possible.

Falling down is part of growing up, Petroski observes.

Since the end of World War II, however, the second approach to technology has arisen: Study it carefully first, understand everything, then build the final operational device. This is basically a wartime approach, and it has hung on because we have been fighting a war for the last forty-five (or seventy) years and we won it only recently. This approach has its roots in the development of the atomic

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Editorial and Advertising: Analog Science Fiction and Fact, 1540 Broadway, New York NY 10036
Subscriptions: Analog Science Fiction and Fact, P.O. Box 5133, Harlan, IA 51593-5133 ISSN 1059-2113
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bomb when there was no time and not enough materials to do it any other way. It was further reinforced during the Cold War by the design, development, and testing of long-range artillery shells known as ballistic missiles. (However, experimental artillery devices are indeed built, tested, broken and improved at places like the U.S. Army's Aberdeen Proving Ground. The M16 assault rifle is the result of dozens of failed experimental rifles, for example, and it in turn will be replaced because of its shortcomings.)

However, many present-day graduates of engineering schools don't understand the need to experiment, to test, and to break the things they've designed. They were taught to use computers exclusively in the design process. Few of them question the computer programs they use.

This was apparent even as long ago as 1984 when I was the keynote and postnote speaker at the 50th Anniversary Symposium of the National Society of Professional Engineers at Purdue University. I remarked that computers were going to play an even larger role in engineering during the coming decade (as they have). The experienced engineers present spent several hours discussing how to ensure that the software didn't contain errors and shortcomings. The answer was to build a few experimental devices with the software first before trusting it.

In later articles and lectures, I further commented on the fact that present-day engineering graduates were

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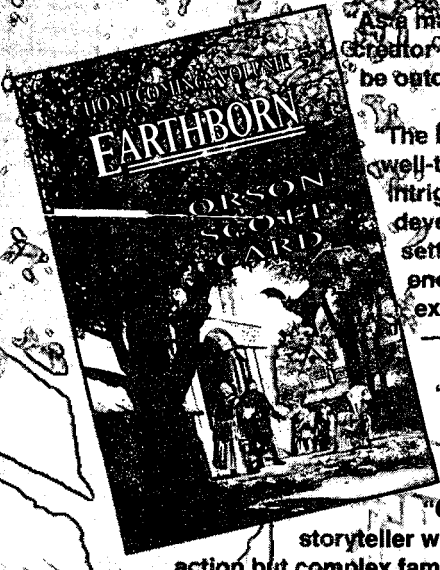

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computer-literate and computer-believing applied scientists, many of whom had never "bent tin" and built anything they designed with their computers. Surprisingly, NASA picked up one of these articles, *Where Are The Real Engineers?* ("The Alternate View," *Analog*, December 1992) and reprinted it in NASA SP-6101(06), *Issues in NASA Program and Project Management*, published in the Summer of 1993.

Other proponents of "build the perfect device on the first try because you are not allowed to fail" have surfaced recently in various government technical policy positions. Taking their cues from the new applied scientists (modern engineers), they don't believe that experimental devices are necessary, cost-effective, or politically wise. Failures in the present government technology system are not tolerated by those in the system (but are recognized as inevitable by other engineers outside the system who have been allowed and even encouraged to build, test, and fail).

Thus, the "real engineers" have learned the hard way that making a workable device today is better than trying to deliver a perfect device next week. It's also a lot cheaper in both short and long terms. Correcting mistakes when the production lines are rolling is expensive, and there will always be far more of those than you want anyway, no matter what you do. In the commercial arena where costs are a far greater factor than in government work (at least to date), good enough is indeed the enemy of the best.

Before the DC-X, we didn't build an experimental space vehicle, an X-ship, for a quarter of a century. On the other hand, experimental airplanes have been built and they have an outstanding record of contributing to both the military and commercial applications of the aerospace engineering art. (Note that I used the word "art"; any commercial engineer knows that's what engineering really is because he's learned that it's not 100% foolproof, not when new technology is incorporated into the mix.)

The space shuttle was preceded by experimental lifting bodies—the unmanned ASSET series and the manned M2-F2, HL-20, and X-24. But government aerospace engineers and managers, supported by the non-technical policy makers, were so buoyed by the success of the Saturn series of Moon rockets (built off the drawing boards

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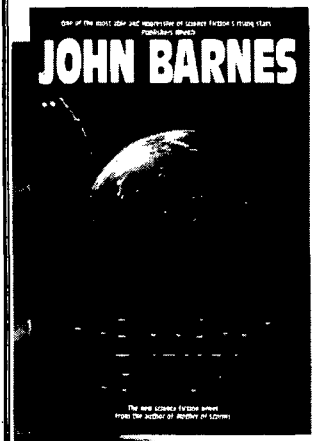

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but with existing technology and nearly twenty-five years of experience in the von Braun team) that no space shuttle X-vehicles were designed, built, or tested. The first space shuttle was launched all-up and manned on April 12, 1981.

Thus, the space shuttle itself has turned out to be an X-vehicle masquerading as an operational system. Any careful look at what is required to prepare one for flight reveals this to a discriminating aircraft engineer or pilot.

Therefore, government space transportation today finds itself tightly wedded to "perfect vehicles" that are not. No failure is tolerated, so everything must be carefully studied first. This is an endless quest for wall-to-wall data and always "one more data point to get." However, any real engineer knows it's impossible to understand everything without designing, building, and busting experimental devices.

I made an unappreciated observation to the Delta Clipper team over a year ago when the DC-X was being designed. "Build two or three," I advised them, "because you will break one. In fact, if you don't bust it, it means you didn't need it in the first place. Experimental vehicles should be broken. So make three while you're making one because the additional ones don't add that much to the cost. Then you can break two of them, find the failure in the design, give the surviving ship to the National Air and Space Museum, and proceed to build the next experimental vehicle that won't fail the same way."

Building X-ships is the fast track and the cheap track. The principle is widely used in commercial industry. It has a long and successful history in aerospace development. If we really want to make any progress in bringing down the high costs, long lead times, and low reliability of present-day space launch vehicles that are based on ammunition philosophy as I pointed out in my book, *ICBM, the Making of the Weapon That Changed the World*, we ought to be building and flying space transport X-ships as fast as we can because we know the approach works.

What are my engineering qualifications for making such statements here? I have designed more than 50 operating rockets in the last 38 years. These weren't just paper designs; they were built and flown. Although two of them were full-sized space vehicles and rocketsondes, the remaining small rockets based on my designs have been successfully and safely flown. I always used experimental rockets in the process. *Always*. Safety, time, and cost were paramount factors. Not all my designs have been successful but none have been catastrophically unsuccessful because I built X-vehicles. (Some of my X-vehicles were something less than successful, but that's why I built them.) As Petroski points out, engineering design makes progress because of failures. Failure doesn't always bring a catastrophic result. Most often, it means that the design doesn't live up to all its claims, that it has some shortcomings, or that incorrect compromises were made in the

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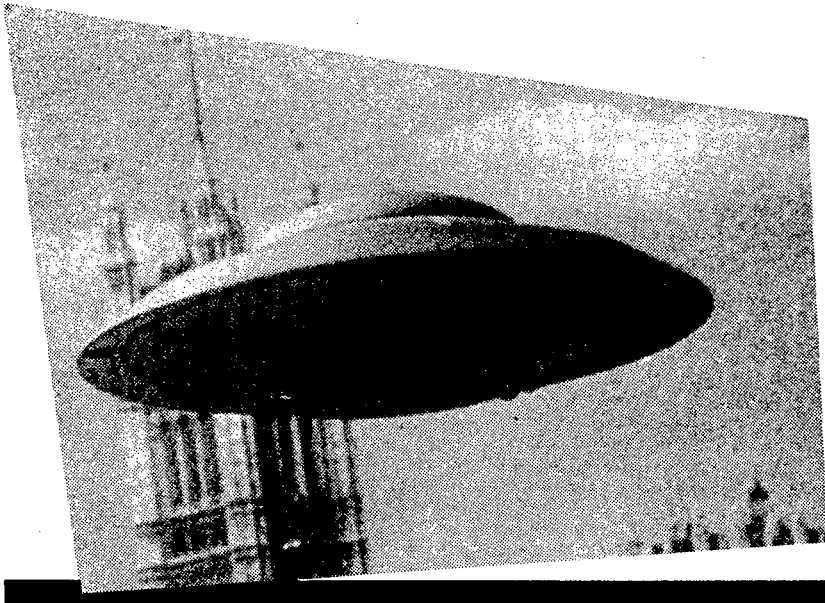

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engineering of the design.

(I was once told by a company, "It's got to look like a rocket, cost one dollar, and fit into the dollar-size box. Do it." Compromises were thus required, and experimental rockets were built and tested in order to make the best possible product.)

Please don't think that I'm talking kid stuff here. Not only have many people—including astronauts Dr. Jay Apt and Charles Walker—gotten started in their aerospace careers building and flying these small rockets, but I can hardly walk into an aerospace company today without running into someone I knew years ago who got started with the little ones. They learned real engineering from them and they learned how to handle technology. Furthermore, the same engineering and technological principles are used in building flying spaceships. These little rockets are just great for teaching budding engineers how to do it. NASA, whose people do a lot of things right in contradiction to the critics, will tell you this, too.

Finally, here is a major reason why the government must fund and see to the building and testing of X-vehicles:

If we are going to have a healthy, vigorous space transportation system providing reliable, responsive, and economical space access to government, commercial, academic, scientific, and everyday users, we need to build a true commercial space transportation industry like our airline industry. That requires venture capital from investors, merchant bankers, and other people who want a return on their investment. In their "due diligence" procedure, they will evaluate all the risks very carefully.

My own contacts with the business and investment communities tell me that (1) they believe safe, reliable, responsive, economical space access is possible, (2) they consider the technical risks to be high at the moment, and (3) they would like to have the federal government do what it has historically done: Reduce these perceived technical risks.

At this time, because of the recent NASA contract awards for RLV technology development, they intend to sit back and wait for these risks to be reduced by means of government X-vehicles. It isn't going to take much to reduce these perceived technical risks (note that I used the qualifier "perceived"). Paper reports and overhead transparencies won't do that. Flying hardware will. It's going to take some X-vehicles, specifically the so-called SX-2 or "son of DC-X" that will scare the hell out of orbit or even reach orbit, come back, and fly again a few days later. It doesn't even have to carry a payload to orbit. After all, the supersonic Bell X-1 didn't carry 144 passengers like the Concorde does, only a single human being named Chuck Yeager. And the supersonic Concorde itself was prefaced by a series of X-ships.

Once the perceived technical risks are reduced by means of building and flying X-vehicles, the investors will be ready to back commercial space transportation. They will turn it into a win-win game, an industry that doesn't

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spend tax dollars but generates tax revenues and creates new jobs just as the airline industry has.

America opened this century by giving humanity the air. America can end this century by giving people everywhere access to space, something closer to us than Washington is to Philadelphia. People should be able to go into space as easily as they can go anywhere on Earth by land, by sea, and by air. Once in space they will do things and create things that will amaze us because they are free people, free to try new things that will make life better for themselves and their children and thus for everyone else as well.

With that dream in mind: ***Build X-vehicles! Fly X-vehicles!*** ■

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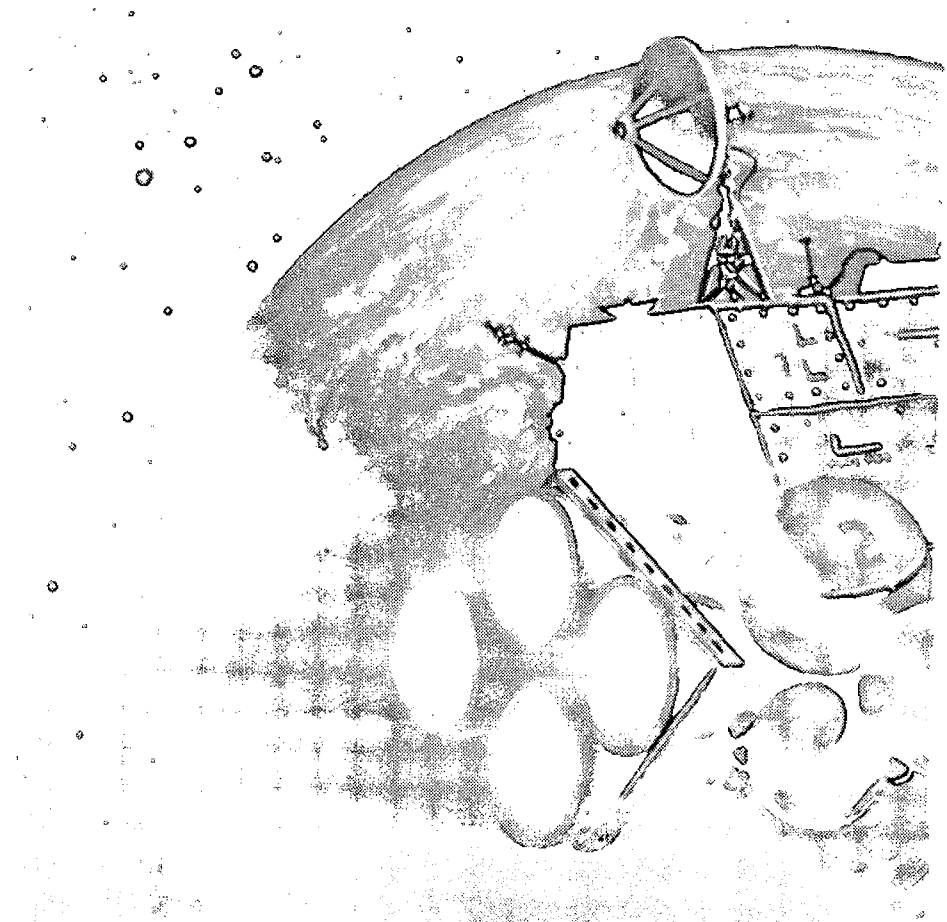

Gregory Bennett

FISH TANK

Alien intelligence may be a lot closer than you think. . . .

Illustration by David Hardy

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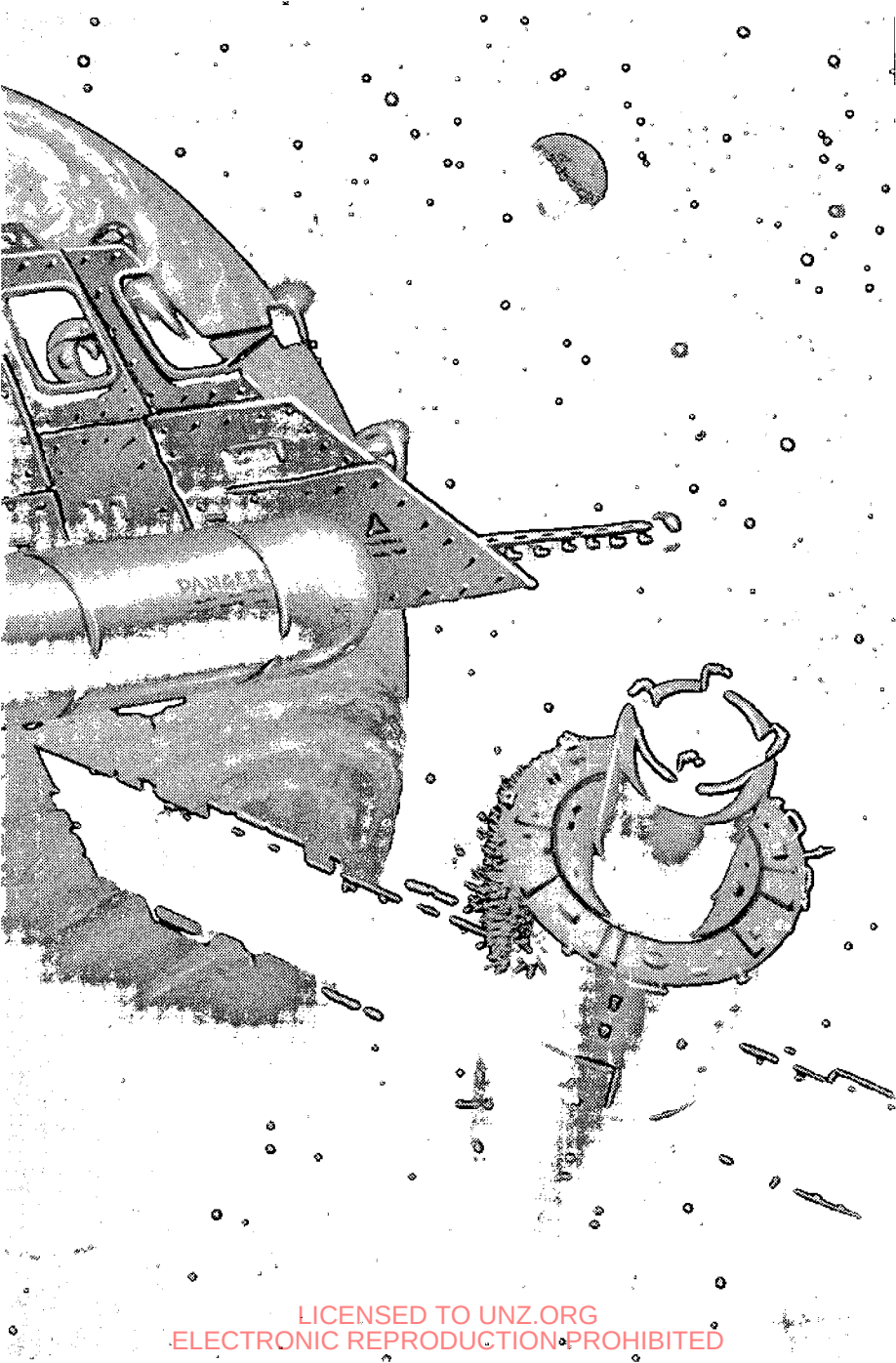

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A few other colonists were out for an early evening stroll along the main promenade of Rantoul High Colony's northern end cap. Jeanette dodged around them, only vaguely mindful of their inquisitive stares. She tried to push her jog into a dead run, but her body refused. Her legs began to ache, reminding her this was only her second day back in the space colony's gravity field after five weeks of servicing zero-g laboratories in Earth orbit. Her medical regimen called for eight weeks reconditioning in full acceleration after the tour, but this was an emergency! If she hurried, she could catch an immediate launch window for OceanLab.

Her immediate goal was to get to Central Station as quickly as she could. It was nearly twenty kilometers down the giant cylinder of the Rantoul space colony, but fortunately she would not have to run the entire distance.

Without breaking her stride, she unclipped her phone from her belt and slipped the instrument over her ear. A stitch of pain lanced her right side when she reached up to tap out a comm code on her phone. Her right leg jerked spasmodically in response, and she stumbled into a cart laden with bouquets of fresh flowers.

I'm really out of shape! Jeanette admonished herself. *Gotta keep up my exercises while I'm on tour.* Muttering apologies to the flower vendor she resumed her jog, deliberately pumping with both arms as she ran.

"Beverly Holmes," the familiar voice spoke from the phone in her ear. "Jeanette? Where are you? I've been waiting at Maxi's for ten minutes already." Beverly was always irritated when Jeanette was late for a date. In return, Beverly's obsession with punctuality irritated her; she had enough of clock-watching while astrogating between the laboratories.

"I'm almost to the tram station, on my way to the docks," she huffed. *Geez! Only two hundred yards and I'm already winded!*

"What? I can't hear you!"

Jeanette reached up to adjust her boom mike. The stitch returned. "I'm on my way to the docks, Bev. Have to cancel our dinner date. Gotta go back out!"

"You can't go out! You just got back to colony two days ago!"

"Don't give me . . . any of your . . . physical therapy crap, Bev." She had to gasp for breath between each word. She slowed to a brisk walk, feeling her pulse pounding in her fingertips. "I'm fine . . . it's just a short trip. Have to go!" She paused to suck a few heavy draughts of air, hoping Beverly would not realize just how winded she was.

"What's the rush?"

"OceanLab is leaking pressure." The pain in her side threatened to double her over. She tried to ignore it. The best she could manage was a stilt-legged walk, but at least she was making progress. "Lots of hits. Meteorites or something."

"Let 'em send someone else. You're not ready."

The doors from the North Cap complex swung open ahead of her. Again picking up her pace to a jog, Jeanette hurried into the twilight outside. She

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fought down a tinge of nausea, reminding herself she was really inside a spacecraft. Agoraphobia; it always nagged her after she returned from weeks in the safe confines of her spacesuit and her tiny laboratories. She looked up toward the comforting vision of the other two land strips of Rantoul High Colony. Lights were beginning to twinkle on as the colony rotated its solar mirrors into their night cycle. She got her bearings as she watched Chanute, Rantoul's companion cylinder, move sedately across the immense window directly above her.

"I don't see how people can stand to live on Earth, with nothing but empty air between them and oblivion," she said.

"We weren't discussing your phobias, Jeanette," Beverly reminded her. "We were talking about the nutty idea of you going back out after only two days of reconditioning. Now just forget it. Send someone else."

"It's gotta be me," she explained. "Nobody else knows OceanLab. I'm the only tech who's ever been inside, and I'm the only one who knows the fish! Besides, I have an exclusive maintenance contract with the Seattle Aquarium!"

A short jog down the foot path brought her to the brightly lit tram station. There were no cars in the station, and no one waiting. This early in the evening the trams would be shuttling empty back down the cylinder to bring more Toulies to the amusements and night clubs of North Cap. Feeling grateful for the solitude, she collapsed onto a seat, and for a moment was aware of little beyond her heaving chest. She had to wipe sweat from her eyes so she could find the buttons on the call panel. With a leaden hand she reached up to punch for a tram.

"Jeanette? You still there?"

"Yeah. Sorry. I was doing something."

"Why are you so eager to get to OceanLab? I thought fish gave you the creeps."

"Not at all!" Jeanette countered. "They're beautiful! At least as long as I don't have to touch them. Besides, Bev, Oscar is on OceanLab! He might be hurt!"

A tram whooshed into the station, braking silently to a sudden stop.

"Oscar?"

"I told you about Oscar. The octopus. He's the most important experiment at OceanLab." She had to use both hands to drag herself out of her seat to board the tram. In the safe confines of the enclosed cabin, she found she could finally relax and catch her breath.

"Oh yeah," Beverly said. "You told me you had a pet octopus on OceanLab you liked to talk to."

"Oscar is more than a pet! He's . . . he's *Oscar!*"

"Jeanette, you are singularly weird." There was a wry smirk in Beverly's voice.

"Thanks, Bev. I love you, too. Gotta ring off now. Water my spider plant for me, will you?"

"Always do. Have a good flight!" Beverly always wished her a good flight, but this time she didn't sound very sincere.

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Jeanette punched for Central Station on the tram's control map and tried to relax as the vehicle glided out of the station. Unless the tram had to pick up someone else, she would be there in fifteen minutes. Just out of North Cap, the tram was still accelerating through the northern groves. She inhaled deeply. The sweet fragrance of orange trees reminded her of all she missed while she was out on tour. After weeks of zero-*g* stuffiness, it was good to have her sense of smell back, if only for a single day. But her responsibility to her customers nagged her; she made another call.

"Yah. Leroy's Services." It was Duke, Leroy's protegé. He sounded distracted. Jeanette heard the snickety rasp of a ratchet wrench in the background. The ratcheting suddenly stopped. "Oh, hi Jeanette! Just recognized your comm code."

"Evening, Duke. Hey, is my suit ready?"

"Sure, back in your locker. I got the pads in your long johns done this afternoon. C'mon in and try 'em on any time."

"I'm on my way there now, Duke," Jeanette said.

He was just a little too long in responding. She wondered what he was thinking. She knew he was fond of her, but tried not to take advantage of it. Duke was a sweet kid, passionately interested in anything she told him about her adventures in the zero-*g* labs. And unabashedly interested in her. It would be too easy to hurt him.

"Tonight?" he finally asked. "But I thought you were going out with Beverly tonight."

"It's sweet of you to remember, Duke. Beverly and I did have plans, but I have to go back out."

There was no hesitation this time. "You can't go out! You just got back!"

Oh great. Here we go again. "Don't worry, Duke. I got lots of exercise on my last tour, hardly any deconditioning at all." It bothered her to lie to him, but if he were seriously worried about her, he might not let her have her suit back. "And I have to go. OceanLab got hit; it's leaking fast. I have to get down there and repair the damage before all the fish die."

"OceanLab?" Excitement tinged his voice. "Is Oscar all right?"

Jeanette smiled to herself. Duke had never seen a live octopus, but he loved stories about Oscar.

"I don't know," she answered. "The control center in Seattle lost all video when the collision occurred. They're only getting environmental status on the backup S-band. He should be OK so far, though; the lab is leaking, but it still has pressure."

"How long 'til you get here?"

"Just a few minutes. I'm already on the tram."

"I'll have your suit ready. I'm recharging the oxygen tanks now."

Jeanette followed the mixed scent of oily silicone grease and pungent disinfectants through the catacombs of Leroy's Services. Duke's boss could fix almost anything that flew in Earth orbit, working in a maze of rooms partitioned out of the structure next to

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Central Station's airlocks. Her locker was one of dozens lining the robing room next to Duke's workshop.

True to his word, Duke had already set up Jeanette's space suit in the donning rack. Her long underwear, really a body suit interwoven with cooling and ventilation tubes, lay on his workbench. Bulky padding sewn into the garment adapted her personal topography to the interior of her secondhand space suit so she wouldn't bang around inside. She caught him with his back to her, adjusting the long johns just so. He was proud of his work, and was obviously hoping to impress her. It worked; she was impressed.

"It looks wonderful!"

Duke jumped, startled. He turned and grinned at her. "Thanks, Jeanette. Everything's ready to go. Need help?"

She really didn't need help—the donning rack was efficiently designed to aid an astronaut even in the full gravity field—but she knew he would feel rewarded if she let him help her.

"Thank you for offering, Duke," she said, answering his grin. She pulled the robing room door closed behind her and kicked off her shoes. "You know how difficult it is to handle the suit in full *g*, and I'm in a hurry." She peeled off her sweater and hesitated just long enough to see Duke flush a charming shade of crimson before turning her back to him.

"Unhook my bra for me?" she requested sweetly. She knew she was teasing him, but the boy deserved some compensation for his interest in her. Besides, she rationalized to herself, she was wearing a long-line iron maiden of a bra, specially designed to help support her back until she got reconditioned. She could undo the hooks herself, but it was a trial.

Duke didn't hesitate to reach for the fasteners, but she could feel the nervous shaking of his fingers transmitted through the bra as he worked. She was surprised that despite his nervousness he worked quickly and efficiently, demonstrating more familiarity with bra hooks than she would have expected. She looked over her shoulder and smiled.

"Do you do this for your girlfriend?"

"Big sister," he stammered. His fingers suddenly seemed to become entangled with the last hook, but he got it undone. "But, uh, she's not built like you, Jeanette."

She wasn't sure why, but it was reassuring to hear that Duke didn't have a girlfriend. Holding the bra loosely in front of her, she turned back toward him and kissed his cheek. "Why thank you, Duke! I didn't realize you'd noticed!"

"I notice; I notice," he muttered.

"Good! Now turn around. Get my long johns for me?"

While his back was turned, she quickly dropped the bra and slipped off her panties along with her shorts. Duke held her undersuit out behind him. For a brief moment she regretted that teasing was as far as she ever went, but the vision of the solitude she would have once she was out in space again overwhelmed the thought. Solitude, far from the crowded space colony, away from the inscrutable wants and needs of oth-

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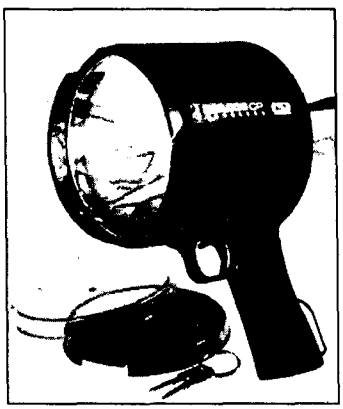

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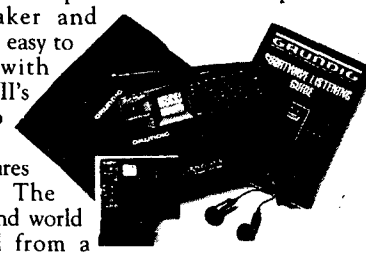

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ers; she was eager to regain it.

With painstaking attention to each detail, she laced herself into the undergarment. This part of the donning process couldn't be hurried. An overlooked maladjustment would later turn into a chafing point which would plague her for hours in transit to the laboratory.

"OK, you can look now," she said as she pulled the final laces closed.

He looked. Padded out to conform to the interior contours of her space suit, she showed considerably less feminine curvature, but he didn't seem to mind. His eyes scanned as if he were mentally erasing her bulky long johns. Her ambivalence returned; he was almost an adult now, only three years younger than her. She should stop thinking of him as the kid who used to follow her around in school. This was adult stuff, and the more she thought about it, the more she wanted to get away from it.

With Duke's help, she stuffed herself into her suit. Torso first, then pants, boots, and gloves. She carried her helmet while he rolled a cart containing her backpack to the airlock.

"Will you take care of my clothes, Duke?" she requested.

"Sure. Aren't you taking anything else with you on this trip? No baggage?"

"Don't have time to pack. It's just a few hours to OceanLab, and I have food there, in the safe-haven supplies."

He stared over her shoulder for a moment, eyes unfocused, brows knitted in worry. When he didn't say anything more, she moved toward the airlock. Finally, he blurted out, "When are you going to get a new scooter, Jeanette? I worry about you, going out in that bucket of bolts."

"Three more tours." She paused at the airlock's inner door. "Then I'll have enough saved up to buy a brand-new Harley; but I might just wait until I can afford a pressurized cabin, too." In her suit, she was just a bit taller than Duke. She leaned down and kissed him, and was rewarded by a disarming look of surprise. He was obviously delighted. "If I get a pressure cab, maybe I can take you with me on tour some time," she cooed.

Duke's eyes widened. "Would you? I'd really like that!"

"Some day, I promise! But first I'd better get out there and protect my job, or there won't be any income to make it happen!"

"But you have lots of labs to take care of. OceanLab is just one—"

"Uh huh," she agreed. "But OceanLab pays the most, and it's the most important. I've told you about the research they're doing in Seattle."

"Yeah, right." Duke didn't hesitate. She wondered if he ever thought of anything but her projects. That she might have so much influence over another person's life both flattered and frightened her. "Zero-*g* deconditioning studies. Besides the fish studies, they're investigating why humans lose their ability to process fatty acids in a weightless environment, and why mollusks don't. That's why Oscar is so important."

"You got it. That octopus was born in zero *g*, yet he's perfectly normal. He's even fathered some children

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now. Hmm, what do you call a baby octopus?"

"Octopups?" Duke suggested.

"Octopuppies! I like it! The second generation of cephalopods born without gravity, and they're all doing fine. Fortunately, Oscar doesn't seem to mind when I have to extract one of them for dissection."

"He doesn't like his children?"

"I'm not sure he realizes they're his own children," Jeanette said. "And there are so many of the little critters—hundreds—I don't think an octopus could get into family values. He just ignores the octopuppies, pays more attention to other animals. There's this one big grouper he seems to be friendly with, and he really likes the lobsters. Of course, he likes to eat lobsters, so that make sense. Actually, Oscar gets along pretty well with all the other animals in the aquarium, all but the jellyfish. He can't stand jellyfish; he's always stuffing them into the snailbots."

"Huh? What's a snailbot?"

"Little robot scavengers that float around in the tanks and clean up the water. It's one of the few concessions we had to make to adapt a salt-water aquarium to zero *g*. We tried live scavengers, but they're all adapted to cleaning up the detritus from the bottom, or from rocks. In OceanLab, the gunk doesn't filter out, so we use a machine to keep the water nice and tidy."

"Maybe OceanLab will get an Earth scavenger to adapt?"

"Could be, but the bots are working well so far. Snailbots to clean up, lungbots to aerate the water. Except for one general-purpose robot with lots of little manipulators, those are the only machines I need to keep everything going smoothly." She thought of how much time she was investing in this friendly chat and glanced at her watch. "Until now, that is. I'd better get going. Eleven minutes to launch." She surprised Duke, and herself, by kissing him again before she donned her helmet and stepped into the airlock.

Midway Marina was a lacework of catwalks suspended below Rantoul High Colony's exterior shell. The Sun had just set when she emerged from the airlock, but it would be back again in one minute as the colony completed half of its lethargic rotation. She was happy to see that Rantoul Departure Control had already switched on the marina lights for her. An armada of space ships, everything from little unpressurized scooters to large family-sized yachts, hung suspended from the network of overhead rails.

She carefully made her way along the open metal grid to her own scooter, towing her backpack behind her in its little cart. Gravity wasn't noticeably higher down in the marina, just a few hundredths of a *g* above normal, but her heavy suit reminded her just how out of shape she was. She was exhausted by the time she had her backpack installed in its cradle in her scooter.

Duke was right; she really needed a new scooter. The vehicle she rode on every tour was more hope and promise than engineering elegance. The whole contraption was made up

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of second-hand parts never intended to serve their current function. Still, she was proud of it; except for a little help from Leroy and Duke, she'd done all the work herself.

With painstaking, deliberate care, she climbed down into her cabin. Production-model space freighters had elegant command centers, but her cabin was nothing more than a collection of flat metal plates welded around her scooter's central rail. The plates protected her from micrometeorites and provided a heat sink to stabilize the ambient temperature, but her cabin wasn't even pressurized; she relied on her suit for that. Mirrors, combined with thick leaded windows set in each of the cabin's plates, gave her a reasonably good view in all directions.

She looked over her minuscule spacecraft with the same care that Rantoul's safety engineers inspected the colony's hull and life-support systems, paying particular attention to the radiation counters. The giant space colony had grown from an orbiting base which serviced geosynchronous communications satellites, so it was inside the outer reaches of Earth's radiation belts. Like all Toulie children, she learned respect for shielding in kindergarten and was most careful to assure her scooter would protect her while she was away from the colony. With the bulk of fuel tanks attached to its plates and a network of thin wires which generated a magnetic field to deflect charged particles, Jeanette's spacecraft kept the worst of the radiation from reaching her.

Her scooter's backbone was a rail scavenged from some long-forgotten scientific pallet. At the back end of the rail was a cluster of station-keeping rockets salvaged from a dead communications satellite. Fuel tanks strapped to the center of the rail supplemented those attached to the craft's shielding plates. Jeanette rode inside her makeshift cabin motorcycle-style, strapped onto her seat with her legs on either side of the rail. The scooter hung from a cargo launch cradle, ready to be boosted into space by the colony's electromagnetic launcher.

"Rantoul Departure, Flutterbye One," she called on her suit radio. "Request launch for OceanLab." The request was simple ceremony; they knew where she was going. She had already called ahead so Departure Control would have her trajectory calculations ready.

"Roger, Jeanette," Departure Control answered. She recognized the voice, an elderly man who decided to retire in the comfort of South Cap's low-gravity community. She had never met him, didn't even know his name, but it was the same voice that sent her off on each tour and welcomed her home when she returned. "Hang on. We're moving you to the launch station."

With a little jerk, her scooter started moving. The launch cradle above her crawled along its track until she was extracted from her parking spot in the marina and aligned perfectly with the long axis of the cylindrical colony. Her control panel winked green, indicating the cradle's

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satisfaction with its latch into launch position.

"Rantoul Departure, ready for launch," she called. Her clock showed less than a minute to go. She leaned back against her suit, braced for acceleration.

"Flutterbye One, Rantoul Departure. Cleared for autolaunch at— Uh oh. Flutterbye One, hold." A brief pause, then, "We've got some bad news for you, Jeanette. You'll have to hold for a while. Colorado Springs says your traj takes you right through the debris cloud that hit OceanLab."

"But I can't wait!" she protested. "OceanLab is leaking!"

"We know, Jeanette, but if you launch now, that debris cloud would do to your scooter the same thing it did to OceanLab."

"I'm armored," she said. She thought it shouldn't be necessary to point out the obvious, but people were chosen to work in Rantoul's transportation system based on their meticulous attention to detail. Safety was always more important to them than getting people to their destination.

"You are, but your engines aren't. At best, you'd wind up being disabled, and we might not be able to get a rescue vehicle to you in time. Besides, you don't want to have to pay for a rescue."

"Hey, the bounty on this unscheduled service would more than cover a rescue flight!" She was getting desperate. With each passing second, OceanLab lost a bit more of its atmosphere.

A different voice, stern and feminine, rang in her headphones. "Flutterbye One, Rantoul Departure Control. Your launch window opens in 132 minutes. We can continue to provide keep-alive power to your spacecraft if you care to hold where you are, or we can move you back to your berth. Say your intentions."

Jeanette sighed. She knew Maisie Johnson; trying to charm her way past Rantoul's safety chief was hopeless. "I'll wait it out here," she said. "Don't have time to get out of my suit anyway."

"OK, Jeanette, we're still with you," Maisie answered. "We've apprised the Seattle Aquarium of your mission status. They want to chat. Want me to connect you to them?"

"Thanks Maisie. Please do." She relaxed against her suit and watched the Universe rotate around her.

"Jeanette, Mark Blevin here, at the Seattle Aquarium. Don't believe we've met. I'm the director of life science research down here. We've heard about your mission delay, and thought you'd like to hear about OceanLab's status."

So the aquarium had the brass on line for this one! Jeanette glanced up at the Earth. The terminator was approaching North America's eastern seaboard; people in Greenwich would be starting to think about lunch. The man got up in the middle of the night just to talk to her! "No, Dr. Blevin, I'm sure we haven't met. I've never been to Earth. But I recognize your name from the OceanLab manuals. Yes, please, tell me about the laboratory."

There was a brief transmission de-

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lay before Blevin responded. "Call me Mark, please. We don't stand on ceremony here. Well, the report I've got says the leak rate was slowing for a while as the pressure dropped, but all at once the pressure went back up, almost to normal, and the leak rate stepped up with it. At the same time relative humidity in the lab went up to 100 percent."

"It sounds like one of the aquariums broke open," Jeanette said.

Another brief delay. "That's what we think, too. From what we can tell, all the punctures are in the dry section of the lab, but we don't think it's so dry any more. Is that going to cause a problem for you? Can you still patch the leaks?"

She thought about the emergency patches in OceanLab's equipment lockers. "No, I don't think it'll be a problem. The water shouldn't bother the adhesive on the patches."

"How about the fish?" she asked.

"We don't know. We don't have a good model for the effects of explosive decompression on fish. Half my folks argue it was a trivial pressure drop, only a fraction of a bar. The other half keep pointing out what happens when we try to bring deep-ocean fish to the surface too fast. We really won't know until you get there."

"OK, Mark; I understand. How long do I have before it's hopeless? Is there enough time for me to stop the leaks before the rest of the fish die? It'll take me at least an hour to patch the leaks, assuming I can find them as soon as I arrive."

"We've run out the predictions, Jeanette. It looks pretty bleak. The lab will be near vacuum before you complete your rendezvous. There might have been some hope if you could have launched from Rantoul on schedule, but that opportunity is gone now. In any case, we'd like you to put top priority on retrieving specimen one ten stroke nine one, the big octopus. Dead or alive."

One ten stroke nine one? Oscar. Oh, Oscar! By rolling her shoulder, she managed to snake a hand inside her helmet to wipe her eyes. She sniffed back a tear and answered. "OK, I'll do that. Uh, Mark, could you let me think for a while?"

"Sure, Jeanette. Call us if you need us. My folks tell me once you're free of Rantoul, we'll be able to talk to you direct on your S-band radio during the first half of your flight. And good luck! Seattle Aquarium out."

"Flutterbye One out."

The Sun rose again as Central Station's launcher rotated into daylight, but it could not dispel her gloom. Try as she might, she was unable to drive the image of her octopus friend from her mind. Oscar, frightened and confused, with no way to understand what was happening, was suffocating. One of the tanks broke. Was it his? Was he already dead, a mass of contusions from gas bubbles expanding in his little cephalopod arteries?

Of all the creatures in all her laboratories; Oscar was her favorite. The apes in FreedomLab provided continuous amusement, but they just weren't as personable as that little oc-

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topus. Oscar loved to play. He spent his days chasing fish and stalking lobsters. One of his favorite games was to gather little air bubbles floating in the zero-*g* aquarium until he had one big bubble. Then he would climb inside and sit there in a compact lump, watching Jeanette while he paddled around with a few tentacles protruding through bubble wall.

Every time she entered the lab, he would rush to the aquarium's glass partition to greet her, waving his tentacles in excitement. Complex patterns of color, reds and grays with hints of blue and green, rippled along his body in time with his waving. Sometimes he entertained her by spreading out all eight tentacles from his air bubble, becoming an eight-pointed star dancing through the water. Other times he glided rhythmically back and forth on his jet, swooping in graceful loops with a trail of bubbles marking his passage the way a precision astrobatic team trailed glowing smoke.

OceanLab had one port in its wet lab, a leftover from its early days as life sciences research facility on a long-retired space station. On the video from the lab, Jeanette had seen Oscar spend hours looking out the port whenever she wasn't aboard. She often wondered if he were looking for her, waiting for her to return.

She would return, but she feared that this time there would be no Oscar pressed against the glass waiting for her. There was nothing she could do about it. Nothing but wait. And cry.

"Flutterbye One, Rantoul Departure Control. Five minutes to launch." The voice startled her awake. It was the old man again. "Still there, Jeanette?"

"I'm awake. Board's all green. Strapped in. Engine check . . . good engines. OK, brakes free. Good comm with the launch cradle. Flutterbye One ready for launch."

"Flutterbye One, three minutes and counting. It'll be quite a boost, Jeanette, three and half *g*'s almost all the way to the end of the cylinder before release. Hold onto your lunch!"

Her instrument panel counted down to zero, and the acceleration hit her. She felt her scooter bend beneath her and then snap back. The outer shell of Rantoul High Colony raced past, waving up and down above her. The acceleration was constant, but it felt like pressure was building up continuously against her back. Her scooter's oscillation tightened into a tooth-numbing vibration. She mentally thanked Duke for the job he did in adjusting her padding; there were no pinch points, just a heavy hand flattening her against the back of her space suit.

The Sun blazed into view past the end of the colony, dazzling her before she could close her eyes. Then suddenly—*Kerchunk!* Release! *Zero g!* Her scooter throbbed in response, giving her a wild ride until its mechanical oscillations settled down. With reflexes honed by more than a hundred launches, her mind automatically adapted to the disorientation as she reswallowed her stomach.

Away from the colony, she had no reference points to attach her mind

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to. Only the faint motion of the starfield, residual rotation left over from the space colony's lethargic spin, gave her a clue that she was not lying still in space. She tapped a button to stop the rotation so her antennas could seek out their targets. By flipping a cover over the forward viewport, she blocked out the Sun, darkening the cabin so she could better admire the blue and white half globe of the Earth hanging in space above her.

"Flutterbye One, good trajectory," Departure Control reported a few seconds later.

"Thanks for the helping hand, Rantoul," she answered. It was what she always said at the start of a tour. "See you in a few!"

"Have a good flight, Jeanette. We're turning you over to Earth traffic control. Rantoul High Colony Departure Control Out."

She watched her comm display automatically cycle to the frequency for Groundhog Central. "Flutterbye One, Colorado Springs, with you in transit via NavStar Forty Seven. We see a good trajectory for OceanLab. You'll have a rendezvous burn in 319 minutes."

"Colorado Springs, Flutterbye One. Roger. Good comm and traj. Request to go off tracking for direct link to Seattle."

"Flutterbye One, off-track comm's approved. They're waiting for you."

"OK. Recontact in one hour. I'll monitor for an emergency breakthrough message. Flutterbye One out."

Her comm panel balked when she punched in the Seattle aquarium's calling code. With a sigh, she rolled her scooter until her antenna could establish a good signal with the northwestern United States. Groundhog Central used satellites for the link but the aquarium's big antenna was above her on the Earth itself. Along with assurance it had acquired the signal, the comm panel told her she had an incoming call.

"Miz Ryan, Seattle Aquarium here." The caller spoke quickly in wavering tenor tones—a young kid, excited or nervous about something, maybe both.

"Jeanette Ryan on Flutterbye One. Go ahead, Seattle."

"Oh good! Miz Ryan, this is Charles A. French," her contact replied. "Dr. Blevin is taking a nap and I didn't want to wake him, but we didn't want to miss the chance to tell you what we know. We have an update on the conditions at OceanLab."

Aha! The son of the aquarium's director. Which means his father is probably there, too. They're really hauling out the bigwigs for this one! She was pleased with her audience; she was getting more attention for this one flight than she had ever had before. Despite her penchant for solitude, her tours were mostly an exercise in loneliness. She tended to try to make up for it when she had some human contact.

"Chipper! Pleased to meet you! Your dad has been telling me all about you! Congratulations on making valedictorian! And that's enough of that *miz* crap. Call me Jeanette. Now, what's up?"

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"Sure. Uh, thank you, Jeanette," Chipper French replied. "There's an anomaly in the rate of pressure drop in the laboratory module. That is, it seems to have stopped leaking, or at least it isn't leaking as fast as it should be. You might get there in time to save some of the specimens."

She felt puzzled. "That's odd. None of the maintenance bots at OceanLab has the ability to fix a puncture."

"Er, just a minute. . . ." There was a short pause. "Dad agrees with you. We can't figure it out either. The reduction in leak rate is a series of step functions, so something must be plugging the holes one at a time. Dad thinks it must be some kind of debris moving around, getting sucked toward the punctures and clogging them. If this keeps up, the environmental control system will be able to make up for the loss and hold full atmospheric pressure for several days."

"Hey! Maybe Oscar is patching the leaks!"

"Who?"

"*Octopus vulgaris,* the big one," Jeanette explained. "Specimen one ten stroke nine one."

Another pause. "Dad says there's no way. Octopi are bright, but they're not *that* bright. Even if he understood the need to plug the holes, which isn't likely, he'd never figure out how to use the patches."

"Yeah, of course you're right. I guess I'll find out what it is when I get there. Any further instructions?"

"Just to remind you that specimen one ten stroke nine one is still the highest priority. We still might be able to figure out how the animal processes docosahexaenoic acid by analyzing its muscle tissue. So no matter what, bring back the octopus. Even if it's dead. You understand why that's important, don't you?"

Oscar! Jeanette didn't want to think about the possibility that he might be dead. There was pressure at OceanLab. She just might be able to save him. She wanted to throttle up her scooter's engines, to do anything to get there faster, but with a tight grip on her control panel echoing her clenched teeth she reminded herself there was nothing she could do to thwart the inexorable laws of orbital mechanics. Flutterbye was already on its fastest possible trajectory.

"Yeah, I understand," she said, feeling the quaver in her voice. "DHA is the fatty acid the body uses for brain growth, and the human body can't process fatty acids in zero *g*."

"Dad says you've got it right," Chipper agreed. "That's why asteroid miners' babies are usually retarded if they don't get them into a gravity field."

She winced at the thought of the rockballers' babies; she'd met some of them. "It explains vegetarians' babies, too. They need animal protein to develop their brains."

"That's a big one," Chipper said. "We can feed a larger population down here if we can get everyone to adopt a vegetarian diet, but as long as we need docosahexaenoic acid, we're going to be carnivores. But diets and babies aren't all of it. We're also looking for a way that human muscle tissue can use fatty acids for fuel. Right now your muscles are only burning carbohydrates; the fatty acids

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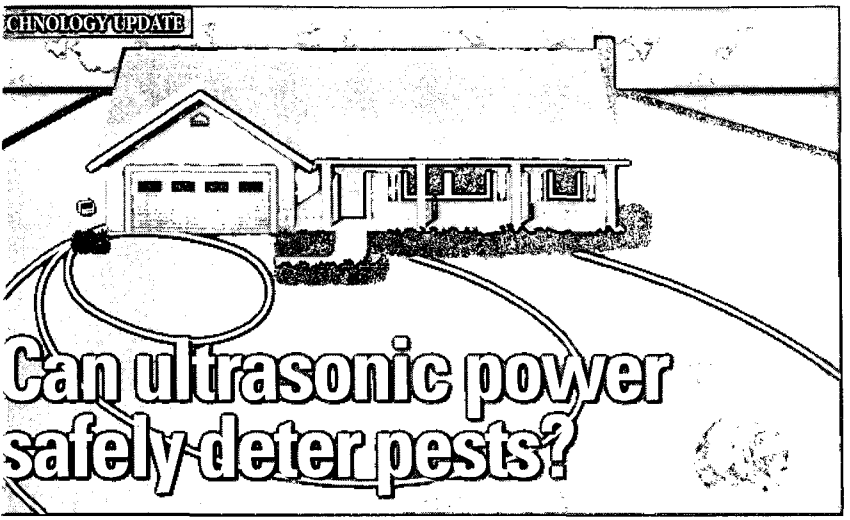

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just build up and eventually get excreted. Some of the doctors down here think it might be worse than cardiovascular deconditioning. You must be familiar with those problems."

"Uh huh. Spacer syndrome. It's the story of my life." She gritted her teeth in determination. "I'll get that specimen even if there's nothing else I can do at the lab."

Her control panel interrupted, chirping for her attention. "Chipper, I have to barbecue my spacecraft for a while to even out the heat load, so I'll have only intermittent communication. If you have anything more for me, you can call through Colorado Springs. I'm monitoring them for breakthroughs. Jeanette Ryan on Flutterbye One out."

A tap on her control stick started the Universe slowly rotating around her. Every time Earth came into view, she strained to search out the tiny speck that would be OceanLab. Of course she couldn't find it. She knew she wouldn't be able to see the laboratory for hours, but felt disappointment nevertheless.

It was the dead of winter in Seattle. The people there would be living under thin layers of overcast clouds for the next couple months, an incessant light drizzle giving them a feeling of being enclosed, isolated from the rest of the world. The thought comforted her. If she ever moved to Earth, she would live in Seattle where she could feel protected by the overcast sky. She whiled away the hours of her flight by wondering what weather must be like.

* * *

Finally it was there, a minuscule spark of light centered in the cross hairs on her trajectory display. Reluctantly, Jeanette turned her scooter around. She could no longer see the lab, but she had to turn her back to it before she lit up her main engines for the rendezvous burn.

When the burn was complete, she was almost on top of her target. OceanLab looked like two cans with wings—the larger laboratory module was crowned with a tiny service module which doubled as an airlock. The wings were OceanLab's solar power arrays and radiators.

The laboratory looked odd, as if it had grown a patch of bristly hair in one spot. She nuzzled a switch on her neck ring to turn on the suit's camera, and puzzled over her mental map of the lab; the bristles were all over the dry section. Her maneuvering rockets left her station-keeping alongside the service module, where she could nurse her vernier jets until the Flutterbye's grapple fixture nestled into a capture latch at the entrance to the service module.

The furry patch on the lab intrigued her, so she decided to fly around OceanLab before going inside. She'd use her suit jets rather than burn up the Flutterbye's precious fuel supply. The cold-gas jets in her suit had originally been intended to allow a space worker to rescue himself if he became detached from his spacecraft. Her suit didn't have a lot of nitrogen for joy-riding, but she could recharge her backpack from the laboratory's atmosphere tanks. A few hours less nitrogen wouldn't make any difference

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to the dying OceanLab. Anticipating the frightening exhilaration of being surrounded by nothing but the cosmos, she pulled herself out of her scooter's protective enclosure and floated free.

She wanted her hands inside her suit for the next maneuver, so she deflated her back bladder to get the volume she needed. By leaning back in her now roomy suit, she could extract both hands from her gloves and pull them inside. Her chest pack had outside switches for the suit's tiny rockets, but the joysticks on her interior control panel gave her the precise control she needed for close piloting. With a few squirts of nitrogen, she floated over the service module and aimed herself at the furry patch on the laboratory.

Up close, it was obvious that OceanLab hadn't really grown hair. The lacy streamers attached to the lab's outer surface were ice, murky water ice tainted with streaks of red. Blood red. She touched one of the icicles. It broke. A spike of ice slipped away to reveal a thin white string protruding rigidly from its murky encasement. She stared at the string for a full minute before she finally realized what it was—a jellyfish tentacle. She thought about that for a moment, and then suddenly had to reswallow her bile. She hated jellyfish. Oscar did too. Perhaps he had taught her to hate them; she liked to watch him do horrible things to the loathsome creatures, tearing off their tentacles or tying them into Gordian knots. His ability to avoid the stinging nematocysts while manipulating the jellyfish never ceased to astound her.

Oscar! Is he all right? She wanted to hurry into the lab to find out, but disciplined herself to complete her survey of the exterior. It was easy to find the punctures. Even where hairy icicles had not formed, streamers of mist and snow showed each point where a meteorite had violated the integrity of the pressure vessel. It soon became obvious to her that patching the leaks was hopeless; there were so many punctures. She did not have enough material to even begin the job. She dismissed that part of the mission from her mind and became intent on collecting as many samples as possible before she ran out of time and had to return to Rantoul High Colony.

When her survey was complete, she flew to the service module's single hatch. A telltale indicated the module was still at zero pressure, just as she had left it at the end of her last visit. Reassured that the hatch between the service module and lab had not been breached, she entered.

With her backpack latched into its donning rack, she activated the service module's status displays and waited for the atmosphere to come up to normal pressure. Salinity measurements in the wet lab were all over the scale; not one of the gauges agreed with another. A major shift in the lab's center of gravity soon after the incident matched her theory that one of the fish tanks had broken open suddenly. And the time history of pressure in the lab was exactly as the folks at the Seattle aquarium had told her—normal up until the meteorite

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puncture, then gradually tapering off after the incident. There was a series of breakpoints in the curve where the rate of pressure drop suddenly slowed. By the time she got there, the lab was back up to its normal pressure, but the repressurization gas supply was dangerously low. Even at its normal leak rate, the lab would not hold out more than a few weeks.

The service module's pressure display leveled out and a valve on the inner hatch popped open with a tiny cloud of mist. Normal pressure. She wiggled out of her suit, glad that the system included heaters for the atmosphere. The bulky long underwear Duke had made for her had a slippery, almost obscenely soft fabric that simplified the job of doffing her space suit in zero gravity.

Immediately, she moved to the window in the hatch separating her from the lab, but it was misted over. Her own reflection grinned back at her, a clown face of smeared makeup. She tried to scold herself for not taking a few seconds to wash her face once she'd canceled her dinner date with Beverly, but a new observation brought back her mirth. The odd bulges of her padded underwear and the Medusa cloud of hair surrounding her face added even more clownishness to her appearance. Still, she was happy Duke had done such a good job on the underwear; in addition to keeping her cool, it kept her from floating around and chafing on every joint in her suit.

"Can't let Oscar see me like this!" she said aloud. She slipped out of her longjohns and scrubbed off her makeup with a wet towel from OceanLab's tiny personal hygiene station. She rummaged through storage lockers for something to wear in the lab, but knew the search was futile. She didn't store clothing at OceanLab, and no one else ever came there. A couple towels might serve as a makeshift bikini, but it didn't seem worth the bother. She regretted not taking the time to grab some shorts and a T-shirt before leaving Rantoul, but when she left the space colony, she didn't know how much time she would have before her launch.

Oh well, personal prudishness aside, nobody will see me, she reminded herself.

She had not even brought a ribbon to tie her hair back, but a wire tie would suffice. Then, with a snap of her chin toward her suit, she thought of something. She hurried to the donning rack, reaching up inside to her helmet's neck ring, and switched off the video recorder. She could edit out any interesting parts before transmitting the data to the Seattle Aquarium. As an afterthought, she turned the recorder back on, in audio-only mode.

"Well, I've learned all I can from the instruments. Let's see what the lab looks like."

Gray fog enveloped her as soon as she had cranked open the laboratory door. Droplets of water coalesced and clung to her skin. The larger water bubbles wiggled as she moved, giving her an itchy tickling sensation. OceanLab normally smelled faintly of lubricants and ozone, but the mist surrounding her had a fishy odor. When she inhaled the vapor, its salty taste

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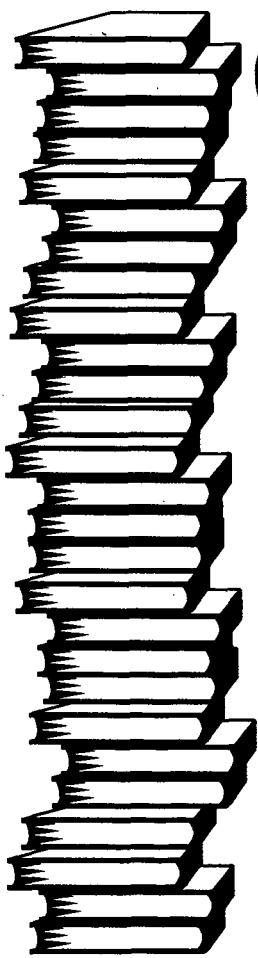

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reminded her of the Japanese restaurant on Rantoul. Beverly often praised that restaurant, saying it smelled like the breeze blowing onshore from the Gulf of Mexico in her native town of Galveston. That was just one of those things where Jeanette could not agree with her friend; she thought the restaurant's odor was repulsive. Besides, some of the things they served there gave her the creeps.

The hatchway felt slippery, and seemed to be vibrating under her touch. She puzzled about the vibration for a moment until she realized it wasn't OceanLab doing the shaking; it was her fingers. In all the time she had been working on OceanLab, she had never actually had to touch the fish. Now, with no knowledge of what really lay beyond the door in front of her, she was about to enter their domain.

She couldn't see much past her reach, so she carefully groped her way through the hatch into the laboratory. The mist was everywhere, but she found she had no problem breathing. That was a relief; she didn't need her suit. To get the suit into the wet lab, she would have had to take it apart and push the pieces through the inner hatch one by one, only to waste more time reassembling it.

The foggy atmosphere forced her to work from memory. She got her bearings by following a series of handrails to the control panels and electronics racks. Some of the displays glowed fuzzily through a coating of water. A faint gurgling sound came from the direction of the air conditioner intakes.

Spherical globules of water floated about, forming into larger globs when they collided. One of them touched her hip. When she unconsciously reached down to brush it away, her hand contacted something solid. She looked. It was a fish, quite dead. The fish's gills were puffed out, a slimy mess of red tissue. Jeanette shrieked in surprise. She batted the dead fish away from her and waited for a wave of revulsion to pass. Only after the fish was lost in the mist did she think to wonder about its species.

"Oscar, where are you?" she called in frustration. Her voice sounded oddly muted, with none of the immediate echoes she was used to hearing in OceanLab. There was no response, but she didn't expect one—even if the octopus recognized her voice, he had no organs for making sound.

Something fluttered near her ear. She turned and found a tiny fingerling pompano inches from her nose. The fish was quite alive, frantically waving its fins and tail as it tried to swim through the humid air. Jeanette had no better idea, so she delicately tapped the pompano with her fingertip, keeping the physical contact as brief as she could. This time she felt only a brief shudder of squeamishness from having to actually touch one of the sea creatures. Her aim was good; the fish drifted off with a gentle spin until it entered a water bubble the size of her space helmet. Once inside the bubble, the pompano momentarily circled and then settled down, apparently content with its return to a more familiar environment.

By moving along the handrails

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around the normally dry part of the laboratory, she was able to continue her investigation. Most of the sea creatures she encountered were dead, but at least a few hundred had survived. She avoided contact with the walls. Spiny urchins and starfish had attached themselves there, each enclosed in a growing water bubble it had scraped off the wall. Undulating spheres of water floated around her, some inhabited by tiny fish, some devoid of obvious life. She dodged around the water bubbles as best she could, especially those inhabited by gruesome-looking baby squid.

Before the incident, OceanLab was partitioned into three sections—the dry lab where she normally did her work, her high-pressure aquarium for deep-sea creatures, and the wet lab. The wet lab occupied almost three-quarters of OceanLab's volume.

From the moment she heard of OceanLab's collision with that debris cloud, Jeanette had been building a scenario in her mind. When she found nothing but more mist and water globules where a rigid pane of glass should be separating the dry lab from the wet, her scenario was confirmed.

She spoke her analysis aloud, hoping her suit could hear her well enough to record her notes. "The station's dry lab must have been punctured, causing a sudden drop in pressure. It had to be the dry lab; if the wet lab had been hit, there wouldn't be a station left. Air is compressible; water is not. I know spacers who found out the hard way what happens when a high-velocity meteoroid hits their liquid fuel tanks—the incompressible fluid transmits the full force of the collision to the tank walls, and the vessel explodes. The same would have happened to OceanLab if the wet section had been punctured."

Repeated contact with the alien water-breathing animals had left her feeling jittery. She hoped her recorded voice would not betray her nervousness as she theorized about the events which led to the demise of OceanLab.

The glass separating the water from the dry lab had to be big and flat so video cameras could monitor all the activity in the aquarium. With the same pressure on both sides, the glass panes only needed to be strong enough to withstand an occasional bump from the human researcher. The service manual said the panes were actually cyanoacrylic, not real silicon glass. The material was several times stronger than what would be needed to stand up to the most clumsy human visitor, but Jeanette's bumbling about in zero gravity was nothing compared to the forces acting across the surface of each pane when pressure in the dry lab suddenly dropped. Air could not flow through the pressure-equalization membranes fast enough to matter, and water would not penetrate the membranes at all. Tons of force must have built up against the transparent panes in seconds, until at least one of them blew out.

"Maybe this wasn't such a great design after all," Jeanette said, continuing her narrative. "Should have

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included some sort of blow-out valve, like we have on our fuel tanks. But—yikes!"

A sputtering sound startled her. A vague dark shape the size of her forearm was moving through the mist toward her. Her mind conjured up irrational images of aquatic horrors. There were sharks among the laboratory's fish population, but the largest were still tiny things no more than six inches long. Even if one of the minuscule predators were stupid enough to attack her, the worst it could do would be to take a small nibble from her exposed hide. But she couldn't stop her mind from imagining. This thing was larger than any shark she had seen in OceanLab, and it made noise.

Fingers clenched on a handrail, arm muscles knotted, she floated. poised to launch herself in any direction away from the approaching menace. Another sputter sounded from the vague apparition, then suddenly it burst forth through a bubble of murky water heading directly toward her. She saw a wide gaping mouth; her mind filled in ravenous sharp teeth and slimy, gruesome gills. Without further thought she heaved against the handrail and propelled herself to the side out of the attacking creature's path. It slid past, gurgling and sputtering as it entered another bubble.

Just before the creature slipped out of her view, she realized what it was. A snailsub. Just a snailsub, doing its best to control itself as it alternately plunged through air and water on its housecleaning rounds of the laboratory. Jeanette knew OceanLab's equipment to the last bolt; despite her panic, her analysis of the snailsub's plight took less than a second. There should have been no real danger, but it was best to get out of its way. Normally the snailsubs moved very slowly, using sonar to avoid running into the wet lab's inhabitants. This one was moving too fast, probably confused because the air moving through its venturis was so much less dense than the water the snailsub expected. It should have turned away before it got so close to a creature as large as her, but perhaps its sonar couldn't cope with the unfamiliar medium either.

Relief from her tension should have come with understanding the mysterious object, but in her panicked flight, she lost her bearings. She had induced a fast rotation; foggy mist spun about her. When she snapped her head around to see where she was going, a globule of water smacked into her face. Then she bumped into a wall.

A stabbing pain lanced her left thigh, outside, just above her knee. Her leg thrashed in reflex and the pain grew sharply more intense. She yelped, as much from surprise as from the pain. Gasping in a lungful of water, she choked, coughing out the brine. Her elbow banged into the wall, and it felt like something else bit her, worse than before, something with a thousand stinging teeth chewing into her hip. Jeanette screamed and kicked, pushing herself away from the wall. Her breath came in short bursts. Every limb quivered in tense apprehension. The thing was

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still biting her!

As she floated, she twisted around to find out what was attacking her. There were no marks on her thigh, just a couple dozen tiny red welts that puffed up into bumps on her skin as she watched. They hurt, pain nerves firing with every pulse of her heart. Contorting herself further, she quickly checked for the second assailant and discovered the source of her problem. There, stuck in the flesh of her hip, she found the reddish brown spines of the sea urchin. A few were driven deep, others bent and broken. She was bleeding from more puncture wounds which surrounded the spines from the luckless urchin.

Cursing herself, the Seattle Aquarium, and everything that lived in water, she began the excruciating process of pulling out the spines one by one. By the time she had them all out, her leg began to feel like it was burning at the site of her wounds. She found a handrail and, after checking for more sea creatures, clung to it until she could calm herself and get her bearings. She could hear the ventilation intake gurgling nearby, and concluded she was on the laboratory's ceiling.

"Oscar, where are you?" she screamed.

She heard a distant, muffled squeak followed by something that sounded for all the world like a bad case of flatulence. Some creature might have responded to her call. But it couldn't be. There were no dolphins here. Nothing in OceanLab made any sound. There should just be the fluttering of desperate fins and the burbling of the robot submarines.

"Get hold of yourself, Jeanette," she told herself. "You came here to do a job. Now just do it."

With the laboratory leaking and no way to find her prized octopus, she decided the best she could do was to recover as many samples as she could while there was still time. Sample collection posed another problem—the only containers she had available to transport the specimens back to Rantoul were the small transparent plastic vials they had originally come in. But the permanent residents of OceanLab had arrived as eggs; only the smallest fingerlings would fit into the vials now. She was forced to settle for bringing home the tiniest animals she could find.

With a cargo net filled with clattering plastic vials trailing behind her, she began a long methodical trek around the lab. Her primary targets were small fish enclosed in their own water bubbles; she could quickly scoop up both the animal and its environment in a single motion without having to actually touch them with her fingers. After collecting a dozen samples, she decided to be more picky and skipped easy targets in favor of searching out a more varied sample of species.

She kept up a running narrative as she worked, calling out the number on each sample container and the aquatic life it contained. Jeanette had long developed a habit of talking to herself whenever she was alone in one of her laboratories, but the dull, anechoic environment was getting to her. She tended to shout, as much to

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reassure herself that there was still a universe beyond her reach as to make sure her helmet microphones would pick up her voice. Occasionally she paused in her work to call for Oscar. Often she thought she could hear that same enigmatic squeak in response, but she began to wonder if it were just her hopeful imagination; octopi do not have voices.

Her venture carried her deeper into the lab until she was working in the volume which had once been the wet lab, the huge salt water aquarium which was OceanLab's primary purpose. Here the environment was more water than air, huge sloppy spheres with identifiable ripples and currents on their surfaces. She would have to be careful not to get her face stuck inside a globule of liquid.

An undulating wall of water stretched vertically from floor to ceiling, separating the back of the wet lab from the erstwhile dry lab. Wavelets sloshing along the wall reminded her of the low-*g* swimming pool in Rantoul High Colony. Suddenly the image of the swimming pool was too strong; vertigo spun through her mind as she lost her gravity orientation. She retreated, clinging to a bent piece of framework until she convinced herself the laboratory floor was *down*.

Lights reflecting off the water wall made it difficult to see what remained of the aquatic life immersed beyond her reach. She didn't want to abandon her search for Oscar as long as she still had time in the lab, but she had exhausted all the likely places she could look in the aerated volume. If the octopus was still alive, he had to be in the water. She was reluctant to go back for her space suit, but the laborious process of disassembling and reassembling the suit seemed to be the only way she could enter the liquid domain. She was on her way back to the service module to retrieve her suit when she came upon the remnants of the laboratory's water lock.

"Finally, a bit of luck," she told herself.

The water lock was a transparent plastic cylinder a meter long, with doors at each end. On every visit to OceanLab, Jeanette had used the water lock to retrieve the little submarines from the aquarium for servicing. The thin, rigid plastic window at one end of the lock was missing, probably popped out in a collision with some other part of the lab when the aquarium wall failed, but the other end was still intact. By inserting the good end into the water, she could use the lock as a sighting device to inspect the regions beyond her reach.

Her makeshift sighting tube allowed her to gather some new varieties of fish. Here, farther from the area which took the brunt of the pressure wave that occurred when the aquarium wall broke, she found very few dead fish. She whooped with joy as she scooped up several tiny flounder with one swipe of a sample container. These flounder were her own discovery, a strain unique to OceanLab—their eyes didn't migrate to the same side of their bodies as the fish matured. The Seattle Aquarium had paid her a huge bonus for the discovery and even named the fish the Ryan

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Strain after her, citing her paper where she speculated that in an environment where there is no sea floor, there was no advantage for the terrestrial species' adaptation to dwelling beneath the sand.

Her joy with recovering samples of the Ryan flounder was quashed when she found Oscar's pet grouper. Near a construction of fake coral—actually a mineral foam made of the slag left over from smelting Moon soil for its aluminum—the big fish hung dormant in the water. Its distended gills told the story; the grouper must have been killed by decompression. Jeanette puzzled over this. If she were right about how the grouper died, it must have been near the wet lab wall when it broke. But if that were the case, why was the animal now so deep in the water? It should have been floating around the dry lab with all the other dead fish. No matter how the grouper died, though, its death was a tragedy. Oscar had long been fond of the big fish. She thought of it as Oscar's pet. Hours of video observations had shown that one of his hobbies was feeding the grouper bits of lobster flesh, a delicacy otherwise unavailable to the big fish.

In her ruminations over the demise of Oscar's pet, she almost overlooked a vital clue to the whereabouts of her cephalopod friend. But a thought nagged at the back of her mind as she continued her search for more specimens. All was not quite right with the gray speckled surface of the fake coral. When the realization hit her, she hurriedly moved her sighting tube back to where she had first spotted the grouper. Indeed, there was a darker vein running through the rock. The surface was smoother in spots. She traced the dark vein, and saw them; molten gold cat's eyes, staring unblinkingly back at her from inside a tiny rounded hole in the rock just a few centimeters beyond the surface of the water. *Oscar!*

"Oscar!" she squealed. A thrill of joy coursed through her mind; tears welled up in her eyes. *He's alive!* She wiped her eyes on her soggy forearm; it didn't help much.

Suddenly the dark vein paled and then turned red. It flashed back into the coral, a tentacle being withdrawn. The speckled golden eyes drew deeper into the hole. They stared back at her through narrow vertical slits rimmed in crimson.

"Oscar, don't you recognize me?" She heard her own voice, shrill with stress and frustration, and realized what was wrong. The octopus was terrified, and had every right to be. Just thinking about the hundreds of suckers clinging to the fake coral told her it would be impossible to extract the animal from his hole by force, not if she wanted to keep him alive. And she desperately wanted to keep him alive.

"Oh, I've frightened you." Now Jeanette lowered her voice, soft and chatty, almost cooing. It was the tone she had always used in talking to Oscar when she visited OceanLab. "It's me, Oscar, Jeanette. You know me, Oscar. You'll be safe now. You can come out now, Oscar." By slowly moving the end of the sighting tube near Oscar's eyes, she allowed him to

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get a good look at her face. The octopus tried to draw even farther away, but he was trapped by the size of the hole he had chosen to hide in.

Then, the tip of one tentacle sneaked out. It was a mottled dark gray now. Good; that was the color Oscar took on when he was relaxed. Tentatively the tentacle touched the transparent window of her sighting tube and explored the rim of the canister. A few suckers pasted themselves against the little window, and she felt a little tug on her sighting tube. When the tube moved, the tentacle immediately let go and disappeared into the hole in the rock. There was just a faint ripple of red this time; he wasn't angry, but his fear showed in the pale gray which enveloped his body.

She kept talking, telling Oscar about her flight to OceanLab and how interesting things were in the laboratory. She didn't expect him to understand her, but these were the subjects she always talked with him about when she first arrived at the lab. If her tone could match what he was used to, he might calm down and come out of his hiding place.

Again a tentacle snaked out, this time feeling its way along the canister of her sighting tube. Jeanette recoiled with a squeal when a few of the suckers touched her face, and again Oscar snapped back into his hole. Gritting her teeth and swallowing hard to quell her feeling of revulsion, she tried reversing the sighting tube, inviting the octopus to hide in this new, convenient hole. He wouldn't budge. Perhaps the hole was too large for him to feel comfortably safe; she was amazed that Oscar could interpolate himself into such a tiny aperture. After several minutes of coaxing, he still hadn't moved. She reluctantly concluded she would have to touch the animal, get him used to her, before he could overcome his fear and release his grip on the rock.

Which meant she would have to overcome her fear of him. A shudder ran up her spine. In a panicked thought, she again considered going after her suit. But if she left him now, he might move to some place where she would never find him before she had to leave OceanLab. It was now or never.

He drew back as her extended finger approached him, but he was in a cul-de-sac. She hesitated for a moment, a heartbeat away from contact, and then clenched her jaw tight and stroked Oscar's face. With one quivering finger she lightly traced the furrow between his bulging eyes. To her surprise, it was not as bad as she had anticipated. He was not at all slimy; his skin had the texture of fine leather, soft yet firm. She kept cooing to him, mouthing inanities in a tone that would put a baby to sleep or inspire playful thoughts in a grown man.

Oscar seemed to relax, just a bit at first. His skin seemed less firm, less tense. She stroked behind his brow ridges. He seemed to enjoy this, moved forward a bit. Eventually he slid a tentacle out from his hiding place and touched her hand. Jeanette winced inwardly, but tried not to let her revulsion show. His suckers pulsed against the skin on the back of

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her hand, but didn't cling. The tentacle moved along her forearm and encircled it, gently exploring, latching on briefly and then releasing. Then to Jeanette's horror he suddenly shot out of his hole and grabbed on to her arm with all eight tentacles.

This time she instinctively recoiled, trying to push herself away from the animal, but there was nothing to push against. Her heart pounded, raising the throbbing ache she felt in the wounds she had received from the sea urchin spines. The lab rotated around her, but her concentration was on the small dark cephalopod attached to her arm. Oscar's golden eyes locked on to her gaze, alive with interest, pupils so dilated they were almost round. Often she had noticed Oscar's eyes tracked independently, giving him the goofy appearance of a half-wit, but for a moment, she felt she was looking into the eyes of an old wizened man. The classic painting of Albert Einstein came to her mind, eyes that hinted of intelligence almost beyond human imagining. Then just as quickly he was again Oscar, her octopus friend, looking around and exploring his environment with his eyes the way he always did.

He was a very young octopus, and as yet not very large. His head seemed disproportionately large compared to photographs she'd seen of terrestrial octopi, but when he fanned himself out he was not much more than two meters across, tentacle tip to tentacle tip. Nevertheless, once Jeanette had convinced herself she could cope with having the sea creature clinging to her arm, she became nervous about his strength. She had seen him rip apart lobsters and huge Australian crayfish; he could just as easily do the same to her forearm. In a vain attempt to coax him away from her without losing him, she again offered her sighting tube as an alternative home. The octopus looked over the defunct water lock, but he either didn't understand why she was showing it to him or just was not interested. He remained affixed to her arm, busily examining the function of her elbow and finger joints with gentle tugs.

She endured her terror when he stroked her nose. Perhaps he was just mimicking the way she had stroked his face. But when he tried to insert a tentacle into her mouth, she frantically slapped the appendage away. While he was exploring her rib cage, she noticed his breathing tube. He was actually out of the water, but Oscar seemed to have no difficulty breathing the humidity-laden air. Her brief surprise at this was dispelled by recalling the many hours he had spent lolling about in air bubbles. Jeanette wanted to log this observation—perhaps even fish might be able to breathe humid air in zero gravity conditions—but was reluctant to raise her voice loud enough for her helmet recorder to hear.

She was prepared when Oscar reached inquisitively for her breast; she had been expecting him to notice them eventually. Gently, she pushed the exploring tentacle away with one finger. The octopus reacted to this by desisting from his explorations, apparently content with the reassurance he found in simply holding on to

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her forearm.

When she was convinced Oscar was not going to leave her, she decided to use her remaining time gathering more life specimens. He didn't seem to mind being dragged around as she worked her way along the handrails, scooping up tiny fish. The way he twisted his body around to follow her movements, his eyes intently tracking her fingers, was a bit disconcerting. When he shifted his grip on her arm, she saw tiny reddish circles where his suckers had been. The discoloration worried her at first, but the marks quickly faded. She took some comfort from observing that at least he wasn't covering her with tiny hickies.

She was just getting used to having him on her arm when, after a few minutes of watching her collect samples, Oscar suddenly released his grip on her and darted off with a squeak and a blatt. She stared after him, mouth agape. It was the same odd series of sounds she had heard before—the sound of the octopus's jet propulsion system, in air.

"Oscar! Come back!" she called in dismay. She tried to kept her voice was low and gentle despite her intense fear that she had lost him.

His jet fired a few more times, somewhere off in the fog. She tried to figure out what direction she should take to pursue him, but he was moving too quickly to follow. All she could do was to call for him to come back, and wait. The pain of waiting was compounded by the throbbing pain from her wounds and her apprehension that she might not find him again.

She had time enough to become seriously worried. She was already out of condition from her previous tour and exhausted from this one. Brief moments of disorientation began to plague her mind. Disorientation was not uncommon at the end of a long tour, especially one where she had been working as hard as she had been that day; but these bouts of dizziness were more severe and more frequent than she had experienced before. She began to wonder if they were more than just the end-of-tour willies, and thought of the venom in sea urchin spines.

After several excruciating minutes, Oscar came sailing back through the mist. Three tentacles grabbed her arm just as before; in each of the other five was coiled a sample tube. He held the tubes in front of him, looking intently at her eyes. Bands of color ran along his tentacles, this time a definite shade of olive among the mottled gray. She obediently examined sample tubes and found that each contained exactly one tiny fish immersed in water, all identical, baby kingfish as best she could tell. The caps were all screwed on tight.

Jeanette was flabbergasted. The octopus had figured out what she was doing, and was trying to help! She found herself smiling at Oscar, and wondered if a smile meant anything to a creature whose mouth was a beak, and usually kept well out of sight.

"Why, thank you, Oscar!" He couldn't possibly understand her, but she hoped her tone would carry the

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message. She continued the same tone with a more private thought. "It's not much help since I already have more than enough kingfish samples, but I do appreciate your effort." She accepted the samples from him, one by one, and inserted the tubes into her cargo net. Again, Oscar followed her every motion. Then, with a quickness she was just beginning to get used to, darted to the net and clung to it. He snaked two tentacles into the net and started manipulating the sample tubes, moving them close to his eyes as if carefully examining each one. To her dismay, he again blasted off into the murk.

There was nothing Jeanette could do but try to stay in the same spot so he could find her again. She kept talking, calling gently to him and wishing he would stay with her.

This time, he returned with another cargo net filled with more sample tubes, and each tube contained a different species: fish of several types, tiny urchins, starfish, baby eels, and even one minuscule jellyfish. The only repetition was in a series of eight vials, each of which had a baby lobster stuffed inside. Jeanette chuckled. Oscar always did have a yen for lobster!

As if in response to her laugh, Oscar released her arm, rolled all eight tentacles into tight coils, and then quickly unrolled them like a circle of party whistles. He repeated the coiling and uncoiling motion several times, until she laughed again. Jeanette remembered seeing him do that before, especially after he had played a particularly nasty trick on a jellyfish. The silliness of it always drew a chuckle from her, but for the first time she realized this tentacle play just might be Oscar's own version of laughter. She tried to imagine what it would be like to have tentacles; it seemed the action would be quite a tension-reliever.

Pop! Whoosh! Her ears suddenly filled with cotton. She could hear a distant whine, like gas moving through a high-pressure line. The lab was losing pressure! A dense funnel cloud appeared a few meters away from her, pointing to the open puncture where there precious air supply was leaking to space. The hole was too small to see through the tiny hurricane it created.

Abruptly Oscar jetted off again toward the wet lab. He returned in seconds with the long stinging tentacles of a jellyfish trailing behind him. With a sickening splat, he slammed the jellyfish down in the middle of the vapor cloud, and the whining stopped. She stared dumbly as the octopus spun in the air in front of her, joyously party-whistling his tentacles. He tagged her arm briefly, filled his cargo net with her remaining empty sample containers, and then just as suddenly launched himself back into the fog.

Again, Jeanette was left with mouth agape. Realization of how the holes in OceanLab got patched pushed her mind past concept shock. She had seen it with her own eyes; she had to accept it. Somehow Oscar had figured out that the holes needed to be patched and used the most convenient material available to him to do

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the job. She tried to think like an octopus, wondering what would lead him to decide to patch the leaks, but found she just didn't know enough about how cephalopods thought to make the transition.

Her painful wounds were beginning to demand as much attention from her as she could devote to Oscar and the sample-collecting process. The sudden drop in pressure seemed to make it even worse. She feared that in her weakened condition she was even more susceptible to the urchins' venom that she normally would be. While Oscar was off on another hunting mission, she considered just staying at OceanLab for a few weeks to recuperate. *It would be fun just watching Oscar jetting around. I wonder what a real hug from an octopus would be like?*

The octopus interrupted her daydreaming when he returned with more samples. He was a little parachute, falling toward her, tentacles spread wide in a braking maneuver in the air. It was nice to be flying in the lunar caverns with her boyfriend, Oscar.

She shook her head violently, trying to clear it. It made her dizzy. "Oscar, what have I been thinking? We have to get out of here! OceanLab is leaking, and I'm losing it. I need medical help, and fast. Let's get to Flutterbye while I can still pilot."

With Oscar clinging to her left arm, she towed the nets full of sample containers into OceanLab's command module. The air was still reasonably clear in the command module, but shining spheres of water had collected there. She wiped a film of water from the environmental control displays to see that the laboratory's leak rate was increasing; Oscar's makeshift jellyfish plugs had been effective for a few hours, but were failing. Faced with a medical emergency, she dared not take the time to use the few mechanical patches she had at the lab. There was nothing to be done but to abandon the laboratory to its fate. Perhaps the Seattle Aquarium would give her a contract to come back and fix it, if they could afford the tons of water needed to refill the fish tanks.

With a wistful sigh, she dogged the laboratory hatch closed for what might be the last time. Its valves closed within seconds, maintaining pressure in the command module as the lab continued to leak its precious atmosphere and water.

Pulling on her underwear put more pressure on her wounds, and her leg increased its protestations in response. She slipped her right arm into its sleeve and tried to coax Oscar to move there so she could finish donning the underwear. The octopus tested the fabric with his tentacles, but was reluctant to release his hold on her left arm. His suckers could gain no purchase on the slippery fabric of her underwear. Talking to him about the problem produced no discernible results, but she finally got him to budge by stuffing her left arm into its sleeve even while he was still clinging to it. He moved ahead of the encroaching fabric to her upper arm and, when that location was obviously no longer safe, snaked out a ten-

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tacle to her rib cage and latched on.

Jeanette felt her skin crawl. All her phobias rushed back in response to tickling, itchy sensation from his suckers. Mentally, she throttled her panic, fighting an incredible desire to bat the creature away, to grab it and tear it off her skin. She thought of his beak, the jagged instrument Oscar used to crack open lobsters and cray-

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fish, pressed against her own delicate hide, and shuddered. It was too much, she had to get him off of her.

"Oscar, you have to let go," she cooed. "I can't put on my space suit while you're holding on to me."

The octopus returned her gaze, his huge black-and-gold eyes imploring. He held close to her, tentacles giving rise to squirmy sensations as they encircled her torso beneath her underwear. Her heart was touched by this. He was behaving like a baby, clinging to its mother.

Or was he? Was he afraid to let go of her, or was he trying to tell her something?

She stared at him. He stared back.

Reality dawned in her mind. Despite her weariness and the progressive influence of toxins in her bloodstream, she suddenly felt quit lucid. "On, no. You can't possibly understand the problem. You're an octopus, a slithery, playful dumb animal. A water-breathing mollusk."

He snuggled even tighter against her, and squeaked with his breathing tube. Again, she swallowed her revulsion, took deep breaths to calm her shudders. She closed her eyes for a few seconds, unsuccessfully trying to make her heart slow down.

"Oscar, you won't fit into one of these little sample containers and I have nothing else to carry you in." The animal just looked at her. "Uh uh. No. It won't work. You cannot ride home in my suit. There's no room! I don't care how small of a space you can hide in, you'd be crushed as soon as I inflated my back bladder, and I can't get my hands into the gloves without doing that."

Oscar rotated his eye turret toward the donning rack and examined her space suit. He looked back at Jeanette. An inquiry.

She shook her head. "Oh, this is ridiculous! There's no way you can understand me, but just forget it. You're not going to ride in my helmet. The very thought is disgusting, and besides it's dangerous. If you blocked my vision at the wrong time, we both could be killed!" She saw that same insistent gaze. He relaxed his grip slightly, and then again snuggled against her, sending more crawlies through her nervous system. This time he squeezed her so hard she had difficulty breathing, but a few quick breaths pulsed her diaphragm enough for Oscar to get the message. He relaxed his grip, slightly.

There was nothing to be done for it; she had to relent. "Oh, Oscar. All right. You can hang on right where you are; I'll just have to endure it. I can use the suit without my underwear, but I'm going to get a lot of bruises. Maybe even frostbite from the lack of thermal balancing. And you just stay out of my helmet!"

She added an afterthought: "And for godsake don't get scared and start releasing ink!"

The bleary fog in Jeanette's mind was worse than the atmosphere inside OceanLab by the time she was ready to contact Colorado Springs for guidance. She told herself she should have skipped a second photo tour outside the laboratory. Her piloting had been clumsy. Her dulled reflexes

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would have been reason enough not to risk it, but banging around in an overlarge suit without the stability provided by her custom longjohns, and having a cephalopodal passenger to boot, made flying with her backpack almost untenable. More than once she had put her suit into a tumble, and every time Oscar went crawling around, trying to get away from the strange sensations. He did not like even the gentle accelerations imparted by her suit's jets.

Repeatedly stopping to wipe condensation from her face plate had slowed her down that much more. By trapping a few globs of water in her suit and overriding her suit's humidity control she had managed to keep the atmosphere moist enough for Oscar, but now she was paying the price.

She had finally made it back to her scooter with a prayer on her lips and an octopus clinging to her neck.

With the photo tour complete, she was strapped into Flutterbye like a rider on a motorcycle, talking with Earth Traffic Control. Her voice sounded thick and slow inside her head. To avoid being crushed when she inflated her back bladder, Oscar had moved to one side with his tentacles wrapped around her waist. He was a squirmy belt, and apparently not at all happy with the pitch dark recesses in which he found himself.

"Flutterbye One, good readback on the engine burn. You're cleared for launch in two hundred seconds exactly." The space traffic controller sounded like the same man she had talked to on her way down. She was surprised when he abandoned his militarily precise diction. "But you don't sound good, Jeanette. Are you all right?"

She explained her condition, including her fears concerning sea urchin venom.

"I understand," Earth Traffic Control replied. "Do you want to declare an emergency?"

"No, no. I'll be OK."

"Then I'm declaring one for you. Flutterbye One, stay on this frequency throughout your flight. We will patch a relay if you want to report to the Seattle Aquarium. Minimize your control inputs; your vessel is go for automatic maneuvers through rendezvous with Rantoul, H.C. Save your energy for the docking, Jeanette. And good luck."

When Flutterbye decided it was time to the launch, the initial boost was very gentle, less than a quarter standard gravity; but Oscar's reaction surprised her. He had squirmed nervously when she tumbled her suit, but this time he crawled around in panic. Jeanette shivered at his touch and said as soothingly as she could, "You're safe, Oscar. Don't worry. And don't ink. *Please* don't ink." No wonder that he was scared. This was more acceleration than he had ever experienced. He was searching for a place to hide.

The vision of where she had found him hiding in OceanLab popped into Jeanette's mind. Frantically, she deflated her back bladder, yanked her hands inside her suit, and reached down for Oscar.

"Don't even *think* about it!" she admonished the writhing octopus.

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Oscar clung to her hand, braiding a few tentacles all down her arm. *Maybe he'll calm down if he can see out.* Slowly, she moved him up her body. With her back bladder deflated out of the way, she could lean back to provide more room, room enough to push Oscar's eye turret up past her neck ring. She clenched her lips tight and let him lean his leathery bag of a head against her cheek. It wasn't as bad as she expected. He was cool to the touch and smelled of fish, but otherwise almost cuddly.

He seemed more calm then, even fascinated by the view through her faceplate. The increased airflow in her helmet might have helped; his breathing seemed less frenetic. Almost reluctantly, he released his grip from lower down and contented himself with holding loosely to her arm. "Just relax and enjoy the view," she purred. "You're a real space traveler now, Oscar. Welcome to the Thousand Miles High club."

They flew the return trip to Rantoul High Colony like that, with Oscar nestled against Jeanette's cheek while she tried to keep up a running narrative of the constellations of stars and spacecraft that came into view. Jeanette found she could not remember the names of some of the objects in the sky, names which should have been familiar to her. But Oscar did not seem to mind her lapses. He just stared out her faceplate, occasionally shifting his grip. After a while she did not even bother to move his tentacles when he searched for something more convenient to hold on to. Once she had to nudge one of his legs away when he became inquisitive about the controls for her suit's jet pack, but only once. Oscar learned quickly what he must not touch.

"Flutterbye One, Rantoul Approach Control. Respond please. You are on a collision course. Mayday mayday mayday." *Words. Just words. Go away, words.* "Flutterbye One, Rantoul Approach Control. Jeanette? Respond please. You are on a collision course. Mayday mayday mayday."

"Wha'? Huh? Oh. Yeah. I think I passed out. Was dreamin'." Jeanette heard someone talking with her voice. It must be her, talking to that nice old man in the Rantoul traffic control center.

"Jeanette? Thank god!" *Yeah, it's the old man. He's nice. I like him.* "We've been talking to your scooter, but we feared the worst. We're not getting any biomed data from your suit."

"Tha's cuz 'm not wearin' any underpanz." She giggled. Oscar attempted a party-whistle, but in the close confines of the space suit, he just wound up bumping her face with a tentacle. "Got m' boyfren' here, too. Say hello, Oxer."

"Flutterbye One, listen carefully. You have to wake up. Your scooter is on a collision course with Rantoul. If you cannot control your craft, we will have to deflect it from its current trajectory. An empty cargo pod is ready to launch to do just that. You will be destroyed by the collision."

"OK," Jeanette responded dully.

"We have been talking to your scooter and have a maneuver set up.

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It will take you to a rendezvous point near the end cap where we can tow you in. But you must enter the execution command. Do you understand, Jeanette? Just enter the maneuver execute command."

The old man wanted her to do something. She liked him. He wasn't like that mean old bitch, Maisie Johnson. "Sure, I can do that. Hang on, Oxer. Here we go."

She pushed the button. Flutterbye spun around and started hitting her. She was too tired to hit back. Oscar didn't like it at all. He grabbed her so hard it hurt.

"Not now, Oxer. I have a headache."

Wiping the mist from her face plate seemed like hard work; she had to concentrate on the task. The space colony loomed huge in her windows and slid past. Then it jumped. Suddenly she was looking at the South Cap freight yard, from outside.

"What're we doin' out here, Oxer? See that li'l door? Tha's where we wanna be. S'OK. We'll jus' fly there."

It seemed like a reasonable plan. She could just park Flutterbye where it was, and fly over to the airlock on her suit jets. Methodically she unfastened her straps and climbed out of her scooter. With a kick, she propelled herself in the general direction of the space colony. Everything started spinning.

"What's wrong with m' fingers? Can't feel the controls," she observed. "This idn't gonna work, Oxer. Lemme jus' take a nap first. G'night."

Oscar the octopus knew nothing of docosahexaenoic acid or what animal bodies did with it. He did know the other animals in his tiny world were generally boring. All except one, that is. The interesting one would come and visit for a few hours, but always left before he could really learn about it. And that one never came to his part of the world. There was always some kind of barrier between them. From watching the way the interesting one moved around, he had concluded the water was much less viscous on the other side of the barrier, like the bubbles he collected.

He had learned to watch through the other barriers so he would know when the interesting one would come. He liked the noises it made, rich in texture and repeated in ever-varying ways. He had learned to attach meaning to the different noises. Some referred to the other creatures in his world. Others meant the interesting one was going to do something to the strange hard-shelled fish that swam in straight lines and generally avoided everyone else. And one noise, a very special noise he loved to hear, seemed to mean the interesting one had directed its attention just toward him. None of the other creatures in Oscar's world ever did that.

He especially liked to watch the interesting one manipulate things with its strange, hard tentacles. The creature's body was all out of proportion—beak misplaced, small tentacles branching off big thick ones, and even smaller tentacles branching from even thicker ones. The stubby little things seemed to be worthless to it, like those lumps on its long body. It

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could not possibly hold anything with those lumps; they just bounced around and got in the way. Those stringy, lifeless tentacles on its head were the strangest. Usually the creature kept them tied up out of the way. Oscar tried to show the creature that he knew about such things by knotting those nasty stringies the jellyfish trailed around. Maybe if the creature saw that Oscar was interesting, too, it would stay longer. Maybe it would teach him more noises. But he could never get the point across. He had resigned himself to a life of boredom, learning what he could by playing with the other animals in his world, and gazing through the little barrier that showed him the world beyond his.

Then the big barrier broke. He was terrified and he hurt, but suddenly there was a whole new world to explore. He found the noisy places where the world beyond was stealing his water. That made sense. There was no water in the world beyond. The interesting one always put on a portable cave before going into that world. But now maybe the world beyond would fill with water and he could go there. He tried to get through one of the little holes, but it was far too small. Something in the world beyond bit off the tip of his tentacle. So he played a joke on the world beyond. He stuffed jellyfish into the holes it had made and stopped the flow of water.

The interesting one usually visited when something interesting happened. Oscar saw it coming in its portable cave. But it made the wrong noises this time, loud noises with bad melody. It was a long time before he overcame his fear of the interesting one's strange new behavior. Eventually, though, it let him touch it. It was warm, good to touch, and more interesting than ever before. It showed him things, and he helped it pick out creatures from his world. He even gave it some of his favorites, so it would know how much he appreciated the attention he was getting.

But then the interesting one was getting ready to leave. Oscar wanted to go with it, to see the world beyond. finally, it consented to let him go in its portable cave. Sometimes it was scary, but he trusted the interesting one. He watched its every move, trying to learn how the interesting one manipulated the world beyond.

Now, after a long, exciting day, Oscar was faced with a conundrum. The interesting one had again stopped telling him about things, and there were indeed very interesting things to explore. The world was spinning around them. Every few seconds something very large would go past. And on that large thing, waving its stubby tentacles, he saw the interesting one wearing its portable cave. The interesting one could not be in two places at the same time, so he concluded this must be yet another interesting one. There might be even more of them! Maybe even as many interesting ones as there were fingerling fish!

But Oscar's interesting one was not doing anything. Maybe it was waiting for him to do it now. It had shown

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him how to gather fish in tiny portable caves, and then let him do this by himself. He wanted to go to the large thing and see the other interesting one, and if he understood the noises his interesting one had made, that is what it wanted, too.

Tentatively, Oscar reached for one of the little joysticks, the one he had seen Jeanette use to stop the world from spinning. He touched it, and then looked at her. She did not brush his tentacle away, did not make protest noises, did not even expose her eyes. He pushed the stick. The world continued to spin, but in a different direction. He pushed the stick the other way, and the world slowed down. By trial and error, he learned to stop the world, and then to move it to where he wanted it to be. He looked to Jeanette for comment, but received no response.

He could see the other suited figure, but now he was even farther away from it. Jeanette had used the other stick to move things closer, so Oscar mimicked her. The other figure was coming closer now, but the world started spinning again. It took two tentacles to keep it all in balance.

Oscar was really beginning to enjoy himself when the other figure reached out for him, and suddenly he could no longer control the world around him. The next few minutes of his life were too strange to think about; he just let the wonders unfold around him and tried to take it all in without trying to analyze it.

Someone was operating some kind of machine, very close to her ear. Jeanette blinked to clear her eyes. No, it was Duke, snoring. He was lying with his mouth agape and head lolled over the back of his chair, feet propped up on a footstool. Normally Duke was clean-shaven, but now he sported a good start at a beard. She stared at him for a while, thinking he looked cute like that.

"He's been here since he brought you in." Jeanette slowly rolled over to face the speaker and saw Beverly, framed in the side rail of her hospital bed. She was dressed in her working duds, a practical one-piece shorts outfit in light green. Her makeup looked fresh. "It's about time you woke up. Maybe now he'll go back to work, so I won't have to keep reassuring Leroy he's not going to go bankrupt while his best technician moons over his girlfriend."

"But I'm not—"

"Ha! So you think."

Jeanette decided to change the subject. "How long have I been here?"

"It'll be three weeks tomorrow. You've been out of it most of the time. Gonna stay awake now?"

"Yeah, I think so. But three weeks! I'd better start calling my customers!" Jeanette started to sit up, and discovered she was wired into the bed by a serpentine array of tubes and wires. Sitting up made her feel dizzy.

"Hold it sister!" Beverly said. "Just lie back and relax. You're going to be with us for a while. If you need to call someone, use the phone by your bed; but you'll find it's all taken care of. All the other independents are pitching in to keep your laboratories going

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while you're laid up."

"Oh no! I'll lose my contracts!" She tried to get up again. The dizziness was worse this time.

"Jeanette, when are you going to learn to trust people? Your friends won't jump your contracts, and won't let the corporations move in. Most of them would have done it for free if I hadn't insisted they hit you up for expenses."

"Oh." Jeanette was surprised to hear she had friends besides Beverly and Duke. She rarely saw the other independent operators to whom Rantoul High Colony was home base, but perhaps their spirit of independence formed a stronger bond than she had realized. Of course, she would have done the same for any one of them—had done, lending a hand where she could to keep the contracts out of the hands of the corporations—but this was the first time she needed help herself. Her vulnerability was unsettling. "Will I have enough to pay my hospital bill?"

"Don't worry about it. The Seattle Aquarium is taking care of it. They were really concerned about you. Dr. French had a big argument with Maisie Johnson about sending a rescue flight to pick you up while you were on your way back. He was willing to pay for it, but there was no trajectory solution for any of the available ships."

"That was sweet of him, but he should have let Chipper handle it," Jeanette said. "Dr. French is a brilliant biologist, but he just doesn't twig to orbital mechanics."

"That's what Maisie said, too. Once he heard you had that octopus with you—"

"Oscar! What happened to Oscar?"

Suddenly, Duke laughed. "I was wondering when you were going remember him," he said. Despite her concern for the octopus, Jeanette felt herself dimpling into a broad smile as she laboriously turned herself around to face him. She could see the good news on his face; he was grinning at her, waiting for her to ask.

"Well?"

Instead of answering her directly, he ceremoniously lifted the television from the side table and unfolded it. He punched a comm code into the television before handing it to her. The image looked like OceanLab as she had last seen it, vague mist and transparent balls of water floating in front of a wall of buttons and knobs. The spacesuit mounted on the wall looked like hers.

She was relieved when Beverly moved around to stand next to Duke. That way she didn't have to keep rolling back and forth to see them both. "Mark Blevin wanted us to send him down to Seattle," Beverly said.

Duke snorted. "No way! When I found him in your suit with you, I thought I'd keep him in a tank at the shop, but as soon as we got him into *g*, he just slumped to the bottom of the tank and wouldn't budge. He'd never make it on Earth."

"Not used to controlling his buoyancy," Beverly explained.

"That makes sense," Jeanette said. "He was born in zero *g*, never knew anything else. But where is he?"

"Leroy partitioned off a section of

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his maintenance hanger up at South Cap," Duke said. "He already had a full-video phone hookup in there. Blevin stopped his squawking when we promised to send him six hours of video a day."

"And some blood and tissue samples," Beverly added. "Oscar turned out to be a good patient. He doesn't complain when you poke him; he just watches."

"Gonna tell her about Molly?" Duke asked.

Jeanette's raised eyebrows communicated the inquiry to Beverly.

"You missed Molly," Beverly said. "We shipped her home yesterday. She's a big female octopus, actually Oscar's distant cousin. Dr. Blevin was worried about how long Oscar would live after all he'd been through, so he didn't waste any time. Molly arrived just a couple days after you got back, first-class cargo from Seattle. I'm afraid your aquatic boyfriend is fickle, Jeanette. He had his hand up her skirt before he even said hello!"

"That's not true!" Duke protested. "Oscar was the perfect gentlemen. He showed her how to fly in zero *g*—."

"Just strutting his stuff," Beverly said. "Showing off, buzzing around her like a rocket-powered zebra."

"Did she answer his zebra stripes?" Jeanette asked.

"Well, yes," Beverly said.

"Then Duke is right; he was a perfect gentleman. That's their mating display. And he had to reach under her mantle because that's how they do it. Oscar has two tentacles especially adapted to deposit his packet in the correct place."

"Oh, all right," Beverly said. "Spoil my joke, if you must. Anyhow, the aquarium got their sample."

"Oscar must be feeling all right if he's still interested in females," Jeanette said. "But I can't see him! Where is he?"

Duke reached over to the television she was holding and switched on its pickups. "Call him."

She called, carefully using the same tone she had used when she greeted him on regular visits to OceanLab. A whoosh came from the television—no rude noise this time; apparently Oscar had learned better control over his jet in air—and suddenly the screen was filled with his eye turret. Black pupil slits rimmed with swirls of gold stared back at her. A second later he backed off and party-whistled in the air with ripples of green and gray flashing along his body. He moved back into close view and patted the top of his eye turret with a tentacle tip, then curled the tentacle into a rough approximation of the letter J.

"He just said hello to you," Duke said.

Jeanette was startled. She waved to the television and returned the greeting. "He's all right, breathing air?" she asked.

"We were going to fill his new tank with water, but Oscar seems to like it just the way it is."

Beverly added, "As long as he keeps his gills wet, he's probably getting more oxygen than he would in pure water. You can tell when he's feeling a little dry because he'll find a water bubble and stuff it under his mantle."

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It felt so good to see Oscar alive and well, Jeanette found her eyes were misting over. She pressed her fingers against the television screen.

"His vocabulary is growing at an astounding rate," Beverly said.

"He knows words?"

"A couple hundred at least; more every day. Mostly familiar things, water, bubbles, different kinds of fish, and names for the people he's met. Duke taught him your name by showing him your picture and drawing your first initial on the screen. That's when it clicked. We think he already had a rudimentary concept of language because he communicates his feelings with his color displays, and he uses his eyes and tentacles to refer to objects at hand. But when Duke showed him a symbol that referred to something that was not present —you, I mean—he twigged to the idea of words as abstractions. That same day he invented his own sign language and started teaching it to us. He talks about you all the time, but I've never been able to figure out what he's saying."

"But how could a cephalopod—"

"That's what Dr. Blevin is so excited about," Beverly said. "They discovered octopi were among the most intelligent creatures on Earth long ago, but what Oscar can do eclipses his terrestrial cousins." She sighed. "I'm afraid groundhog girls like Molly will always be nothing more than sex objects to him. He couldn't get her interested in any of the things he had to show her; all she wanted to do was hide. Like all octopi, she has the thirty-lobed brain—"

"*Thirty?*" Jeanette said. She kept smiling and waving to Oscar through the television screen. He responded with writhing tentacles and patches of color shifting in complex patterns.

"—Uh, huh, they use it mostly for motor control, posture, and color displays. I've been studying up on the material Mark Blevin sent. Oscar's cranial lobes are much larger, way out of proportion to terrestrial octopi. Since he doesn't have to invest so much of his mind in maintaining posture in a gravity field, he seems to pay attention to other things."

Oscar darted away from the television, and returned seconds later with one of the maintenance bots that normally inhabited Rantoul's zero-*g* cargo holds. The robot's manipulators were missing, and the joystick controls from a space suit had been added. With a wave and a flash of yellow-green, he jetted off on the robot.

"He's showing off again," Beverly said.

"That's his favorite toy. It was Leroy's idea," Duke explained. "Oscar didn't want to leave your suit when we brought you in, so I just shut it down and left it in there with him. Leroy saw him playing with the controls for the suit jets, looking around as if he expected it to fly. Just as an experiment, he cobbled up that little scooter out of parts from old maintenance bots and a retired suit, and sure enough. Oscar took to it right away! It scares me the way he flies so close to things, but Leroy says he's a natural pilot—always knows his orientation and tracks the trajectory of everything around him. The only time he has

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problems is when he runs out of compressed air, but at least he doesn't crash any more. Dr. French wants us to let him try out an astrogation simulator."

Jeanette thought about it for a second. "He might like that; it's an extension of what he's been doing all his life at OceanLab. Gonna do it?"

"As soon as we can move one of the simulators into his zero-*g* tank and seal it against the humidity. The aquarium is paying for the whole thing."

"I want to go see him—" Again, she started to get up but found Beverly's hand firmly planted on her breastbone.

"Oh no you don't, girl," Beverly said. A nervous waver beneath her stern voice betrayed the depth of her concern. "You have months of recovery ahead of you, Jeanette. You're atrophied, decalcified, dehydrated, full of toxins, and have granulomas from sea urchin spines wandering around your body. You're not leaving the *g*-field until I say you're ready! Since Oscar can't come to see you either, the two of you will just have to settle for visiting on television for a while. You're in for a long vacation, so just relax and enjoy it."

There was no choice but to accept it; Beverly was right. For the first time in her life, she had to depend on others, trust their judgment in handling her business matters and trust them to take care of her. "All right," she said, lying back against her pillows. Oscar waved a tentacle as he sped across her television screen. "This time I'll be good."

* * *

Duke was not at all shy about helping Jeanette with her suit this time. As soon as he had secured the last lace of her undersuit, she threw her arms around his neck and kissed him heartily.

"It's been a long time since you've done this for me," she said.

His youthful grin was as disarming as ever. "Almost a year. I remember the last time. I almost lost you then!" He waited while she finished up the laces on his undersuit. She seemed to be having trouble making her fingers work. "You're really excited about this trip, aren't you?"

"More than I can say. It's so good to be going out again. All the time I was in the hospital getting transfusions, and then the months of physical therapy, I've thought about nothing but getting out again in my own ship. But I'll keep my promise. I won't go out without you, as long as you want to go."

Duke smiled and patted her. Snuggled in his arms, she wondered how she could ever have thought of him as a boy. "It's a deal," he said. "Let's see how it goes on this trip. If it's half as much fun as you make it sound, we're partners!"

Beverly knocked and poked her head in the door. "Everybody decent? Oops. Sorry to interrupt."

Duke nodded to her. "S'OK, c'mon in, Bev."

She padded in, wearing an undersuit similar to those worn by the others. "Can somebody help me with these laces? I can't figure out where they go." While Duke was tightening the laces, she added, "I don't know

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how you talked me into this, Jeanette. I'm a colony girl now, not a spacer."

"I didn't talk you into it, the Seattle Aquarium did, with a nice, fat research contract. You've got a better chance at figuring out zero-*g* deconditioning than any other doctor in Earth orbit."

"Well, thanks for putting in a good word for me, anyway."

"You didn't need my help. You got just the calling card you needed when you cracked the code on those enzymes that let babies develop normally in weightlessness."

"Couldn't have done it without the mollusks you brought back from OceanLab. But I guess the Seattle folks did all right by you, too: new contract, new ship to go with it—pressurized, even! Next thing you know they'll be putting up a statue of you at the Pacific Science Center!"

Duke interrupted. "All right, Bev, you're laced in. If the mutual admiration society will kindly get into their shiny new suits, we can get up to South Cap in time for our launch window."

While she was squeezing herself into her new custom-fitted space suit, Jeanette added a thought. "It'll be nice when Rantoul gets a pressurized docking tunnel installed at South Cap. We won't have to put on our suits just to get out to the ship."

"Give 'em some time," Duke said. "It took months to get the material for a permanent zero-*g* dock for your new ship. Leroy and I only finished it a few weeks ago."

"Oh, I didn't mean to sound unappreciative, Duke. I'm anxious to see it," Jeanette said. "Is our new pilot ready for the trip?"

"More than ready," Duke said. "He aced ground school while you were still in the hospital, and even helped design the new control station for the ship. I've been watching him practice rendezvous procedures since the day the new dock was finished. He's a natural, Jeanette. You won't find a better zero-*g* pilot anywhere inside the asteroid belt."

As she was strapping herself into her seat in the Flutterbye Two, Beverly remarked, "Y'know, Jeanette, it's a shame you can't launch from the catapult, but I think that's what finally made me decide to take this job. I just can't stand that sudden drop to zero-*g*. Can't even take the shuttle to Chanute without tossing my cookies all the way."

"It's a small price to pay," Jeanette said. "The F-Two doesn't need the boost, and for the price of a few extra kilos of fuel we get the best pilot in the Galaxy!" She looked toward the forward control station. There was some condensation at the corners of a transparent partition around the control station, but she could clearly see the pilot within.

The pilot turned around from his console and beamed at them with his molten gold cat's eyes. He spoke, tentacles flying over the keys of a model ninety-four Hawking voice encoder. "Why, thank you, Jeanette! Now, as soon as you lumpy humans are ready, we'll launch Flutterbye Two on her maiden voyage. Destination: OceanLab!" ■

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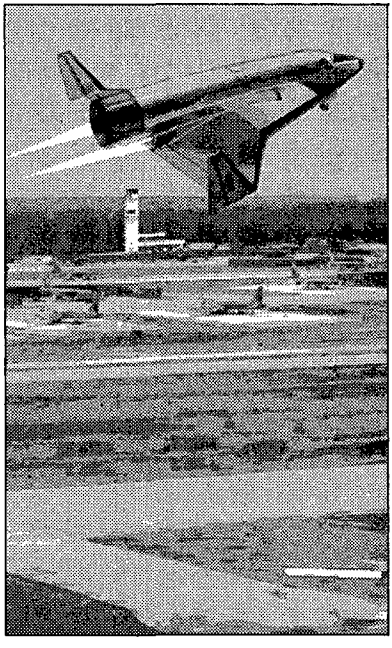
Robert M. Zubrin
and
Mitchell Burnside Clapp

BLACK HORSE: ONE STOP TO ORBIT

Illustration by Ron Fleming

Introduction

Since the dawn of the space age, building a vehicle that can fly to orbit using only a single stage has been the holy grail of astronautics. The problem is that single stage to orbit flight is really hard to do because the velocity change necessary to achieve orbit ("ΔV," 31,000 ft/sec, typically), including losses due to aerodynamic drag, gravity, back pressure on the engines, steering, and so forth, imposes vehicle-full to vehicle-empty mass ratios that are difficult to achieve with current structural technology. The usual approach is to seek more energetic propellants with high specific impulse ("I_{sp}," the number of seconds a pound of fuel can be made to deliver a pound of thrust) values. Alternatively, people have tried air-breathing approaches, which are also



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an attempt to achieve large I_{sp}. The first approach, ultra-high I_{sp} rocket engines, tends to involve propellants that are not very dense and are difficult to handle, such as liquid hydrogen. The second way, using hypersonic airbreathing jets, imposes surpassingly difficult design and operations problems such as those that have afflicted the National Aerospace Plane program.

Three major configurations have been proposed for single stage rocket vehicles: vertical take takeoff/horizontal landing (VTO/HL), such as the SSTO/R vehicle proposed by the NASA Access to Space Study; vertical takeoff/vertical landing (VTO/VL), such as the McDonnell Douglas Delta Clipper; and horizontal takeoff/horizontal landing (HTO/HL), such as the Boeing Reusable Aerospace Vehicle (RASV) or British HOTOL designs. Between the first two of these, there is no obvious distinction in terms of empty weight. Credible design studies appear to give similar weight estimates for similar vehicles. Horizontal takeoff and landing vehicles, however, tend to be much heavier for a given payload because of the unique requirements imposed by runway takeoff, with wing loads at rotation and the weight of landing gear being of particular concern. Because of these inert mass hits, horizontal takeoff and landing vehicle designs generally tend not to be pure single stage to orbit, but rely instead on sled launch or auxiliary boosters to reduce gross weight.

Our purpose is this article is to discuss another approach for operating spaceplanes off conventional runaways with conventional facilities: using in-flight propellant transfer to re-

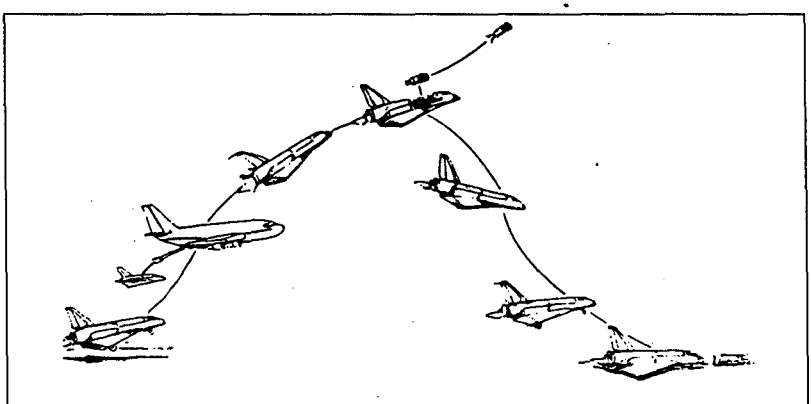

Figure 1:
Aerial propellant transfer (APT) spaceplane flight plan. Because the aircraft takes off light, the mass of wings and landing gear is greatly reduced.

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duce the takeoff gross weight of a rocket-powered aircraft, and hence its size, weight, and cost. This is not an attempt to solve the single stage to orbit problem by means of increasing I_{sp}, but by decreasing ΔV. It turns out that if you begin the mission to space from tanker altitude and airspeed, the amount of propellant that must be expended overcoming drag and gravity losses is greatly reduced, the vehicle tankage, wings and landing gear all become smaller, and everything becomes a whole lot easier.

The Aerial Propellant Transfer Spaceplane

The general concept of the operation of an aerial propellant transfer (APT) spaceplane is shown in Fig. 1. The spaceplane, carrying only a fraction of its required propellant, takes off a runway in a conventional manner using either rocket power or a set of air-breathing engines and climbs to rendezvous with a tanker, typically at an altitude between 20,000 and 40,000 ft., depending on the spaceplane design. The tanker transfers the remainder of the required propellant and departs, after which the spaceplane fires its main rocket engines at full throttle and accelerates to low Earth orbit. Upon reaching orbit, the payload is released, possibly to be propelled to higher orbit by its own propulsion system, while the spaceplane re-enters the atmosphere, glides to the vicinity of an airport, and then lands in either an unpowered or rocket or jet powered mode.

There are many variants possible to this basic plan, including selection of propellants, propulsion systems, and refueling scheme. For example, the possibility of a spaceplane using the leverage offered by employing very high specific impulse air-breathing propulsion above the tanker's maximum velocity of Mach 0.85 to cut the rocket's required ΔV to orbit, needs to be considered and traded against the large inert mass penalties and system complexity associated with such jet engines. Use of smaller jet engines for takeoff, loiter, self-ferry and landing offer many operational advantages, but decrease performance.

In the case of refueling scheme, in principle both fuel and oxidizer could be transferred from the tanker to the spaceplane. However, for the propellant combinations of interest, between 72% and 88% of the vehicle's propellant is oxidizer, and therefore the lion's share of the benefit of aerial propellant transfer can be achieved by transferring oxidizer alone, with all fuel loaded on the ground. As such a scheme offers significant gains in simplicity and moderates the amount that the aircraft weight multiplies during refueling at a small cost in system performance, it was the method of choice for all systems included in this article.

Comparison with Alternative SSTO Concepts

It is useful to compare the general characteristics of the APT spaceplane to the three SSTO types that have been considered in the past. These are the Vertical Takeoff/Vertical Lander (VTO/VL), the Vertical Takeoff/Horizontal Lander (VTO/HL), and

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Table 1. Comparison of SSTO Options

Concept	VTO/VL	VTO/HL	HTO/HL	APT
Airframe	Minimal	Small	Large	Small
Landing Gear	Small	Small	Large	Small
Engines	Large	Large	Medium	Small
Expans Varies	1 bar	1 bar	1 bar	0.2 bar
New Infrastruct.	Much	Much	Little	Little
Payload	Medium	Small	None	Medium
P/L Integration	Hard	Hard	Easy	Easy
Pad Site Flex	Low	Low	High	High
Inclination Flex	Low	Low	High	High
Abort Capability	Low	Low	High	High
Self Ferry	Maybe	No	Yes	Yes
Crossrange	Low	Medium	Medium	High
Evolve w/ Jets?	No	No	Yes	Yes
Launch Vehicle?	Yes	Yes	No	Yes
Military A/C?	No	No	Yes	Yes
Passenger A/C?	No	No	Yes	Yes

Overall, the Aerial Propellant Transfer (APT) Vehicle Rates the Highest.

the Horizontal Takeoff/Horizontal Lander (HTO/HL). A summary of all four options is given in Table 1.

The airframe of the VTO/VL is clearly the lightest, but theVTO/HL is not far behind, and because it takes off and lands light, the airframe of the APT spaceplane will be comparable to that of the VTO/HL. The large airframe required by the HTO/HL to take off at runway speeds with a full load of propellant severely penalizes this option by SSTO application.

In the case of landing gear, the VTO/HL and APT pull about even with the VTO/VL, but once again the HTO/HL system is severely penalized due to the excessive weight its gear must support.

In the case of engines, the APT spaceplane is a clear winner. This is because as a horizontal takeoff system, it only needs a system T/W (thrust/weight) ratio of about 0.8, while the vertical takeoff VTO/VL and VTO/HL needs T/W ratios closer to 1.5, effectively doubling their engine mass requirement relative to the APT spaceplane. The HTO/HL will also need larger engines than the APT because it is carrying inert mass penalties in its airframe and landing gear, and because its required ΔV to reach orbit is greater. Furthermore, the VTO/VL, VTO/HL, and HTO/HL rocket engines all must be designed to expand their exhaust gasses to a sea level environmental pressure, while the APT spaceplane rocket engine need only face a maximum back pressure of the air at tanker altitude, which can be as little as 0.2 bar. This

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makes it much easier to achieve optimal rocket engine performance on the APT spaceplane system.

The vertical takeoff options require a lot of expensive new infrastructure in the way of launch pads, while the HTO/HL and APT spaceplane, which use existing airports, require little or none.

The vertical takeoff systems' *payload integration* is much more complex, and *pad site flexibility,* payload orbit *inclination flexibility,* and *abort capability* are much more limited than either the HTO/HL or APT options. The vertical takeoff systems require specialized pads, the HTO/HL and APT systems can take off and land at conventional airports anywhere in the world, and can *ferry* themselves around the world for payload integration, launch operation, or vehicle servicing, as required. The winged options have much greater *cross-range* capability upon reentry than the VTO/VL, with the APT spaceplane having the most, since compared to the VTO/HL or HTO/HL it has the fewest conflicting requirements with the demands to optimize the airframe and trajectory for efficient hypersonic flight. If hypersonic air-breathing propulsion systems should become available, the HTO/HL and APT can *evolve* to take advantage of them, while the vertical takeoff systems cannot.

As a *launch vehicle* the VTO/VL and APT have the highest payload capability, the VTO/HL less, and the HTO/HL none. On the other hand, the APT and the HTO/HL have the potential of functioning as a *revolutionary military* or *civil aircraft,* while the vertical takeoff systems cannot. Thus of the four options considered, *only the APT has the potential of functioning effectively both as a launch vehicle and as a revolutionary ultra-high speed aircraft,* and can therefore be rated as having the highest potential overall.

Alternative Propellants

We've looked at four candidate propellant combinations for use in a APT vehicle; H_2/O_2, CH_4/O_2, RP/O_2, and $JP\text{-}5/H_2O_2$. All of these are non-toxic and non-polluting.

H_2/O_2 offers the highest specific impulse (450 s) of any realistic chemical propellant option. It also offers a relatively high oxidizer/fuel mass ratio (6:1) which is advantageous in an APT spaceplane system, and several off the shelf engines are available. The primary disadvantage of H_2/O_2 is the very low density of hydrogen, which creates the need for large volume tanks which are difficult to incorporate into a reasonable airframe design, and which also creates tankage mass penalties that counter much of the benefit of H_2/O_2's high I_{sp}. An additional disadvantage is the necessity to handle the very cryogenic hydrogen, which stores at 20 K, and is not available to support vehicle operations in many parts of the world.

CH_4/O_2 offers the second highest I_{sp} (385 s), with the benefit of a great increase in propellant density over H_2/O_2 (CH_4 is seven times as dense as hydrogen), allowing tankage sizes and masses to be brought under control. The O_2/CH_4 mixture ratio of 3.5:1 is

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not too bad, and while both CH_4 and O_2 are moderately cryogenic, they both store at the same temperature (around 90 K) so that compact tankage arrangements are possible. Liquid methane, while not a staple at today's airports, is available in most places around the world. In fact, CH_4/O_2 is by far the cheapest rocket propellant combination there is, so that if APT spaceplane operations were to expand to the point where fuel costs were an important factor, this would be a real plus. A significant disadvantage of CH_4/O_2 is that no flight-rated engine is currently available; development of one based on Pratt and Whitney RL-10 engine technology would probably take three years and cost on the order of $30 million.[1]

RP/O_2 (RP is rocket engine grade kerosene) offers a specific impulse of 355 s (using Russian NK-31 engines), and a rather dense propellant combination, only one of whose members is cryogenic. Existing engines achieve their highest specific impulses at mixture ratios of about 2.6:1, which is on the low side from the APT point of view, but the fact that such engines are available off-the-shelf could make RP/O_2 the propellant choice for a near-term APT system.

$JP\text{-}5/H_2O_2$ only offers an I_{sp} of about 330 s, but it is by far the densest of the four propellant combinations considered (H_2O_2 is 1.43 times as dense as water), and burns with a mixture ratio of 7.3:1, very satisfactory from the APT point of view. JP-5 (ordinary jet fuel) is cheap and available at airports everywhere; H_2O_2 is ten times as expensive as LOx but still a lot cheaper than N_2O_4, and is available in many parts of the world. The big advantage of the $JP\text{-}5/H_2O_2$ propellant combination is that it is entirely noncryogenic, so that the required tanker modifications needed to support APT operations will be much less involved than for the other propellant combinations considered. A significant disadvantage of the $JP\text{-}5/H_2O_2$ combination is that no high-performance engine utilizing it is currently available. Modifying a Russian NK-31 might produce a rocket engine with an I_{sp} of 330 s and a T/W of 60 at a program cost of about $25 million[2]. Developing a clean sheet engine to improve the T/W above 60 could cost significantly more.

We conducted a trade study to examine the performance of these four propellant combinations across a range of APT options and compared them against a VTO/HL baseline. The VTO/HL assumed in our study has no jet engines and must perform a 31.1 kft/s ΔV to reach orbit from a launch pad. The VTO/HL has a pad liftoff T/W of 1.5. The three APT spaceplane options included:

The "Mach 0.8" option, in which small turbofans are employed to bring the APT fully loaded with fuel (but no oxidizer) up to rendezvous with the tanker. As the APT is loaded with oxidizer during refueling, the increased thrust required to maintain flight is provided by placing a towing load on the refueling boom. After separation the rocket engines are lit and provide the full 27.9 kft/s required to bring the APT spaceplane to orbit from the tanker's Mach 0.8, 20,000 ft level

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flight condition. The Mach 0.8 APT has a T/W of 1.0 at rocket ignition.

The "Mach 3.0" option, in which larger jet engines are employed that not only can maintain the APT on the tanker until fully fueled but also accelerate the APT spaceplane up to Mach 3.0, prior to ignition of the rocket engines. This reduces the required rocket ΔV to orbit to 24.0 kft/s. The Mach 3.0 APT spaceplane has a T/W of 0.8 at rocket engine ignition.

The "Mach 5.5" option in which subsonic combustion ramjets are employed to bring the APT up to Mach 5.5 prior to rocket ignition. This reduces the required rocket ΔV to orbit to 20.7 kft/s. The Mach 5.5 APT has a T/W of 0.6 at rocket engine ignition.

We assumed that the subsonic L/D (Lift/drag) for APT vehicles was equal to 10, supersonic L/D was set equal to 3. Rocket engines were assumed to have a T/W of 60, jet engines a T/W of 8. Tanks were assumed to have a mass fraction of 4% of the propellant they contain if the propellant was water density; this fraction scaling inversely with the 2/3 power of propellant density.

The results of the analysis are shown in figs. 2, 3, 4, and 5. Fig. 2 shows the ratio of "payload" to vehicle wet mass for the options considered. "Payload" here is defined as that portion of the vehicle dry mass not consumed by tanks, wings, landing gear, rocket or jet engines. You can see that under the VTO/HL mode, only the high-performing H_2/O_2 and CH_4/O_2 propellants can deliver any payload at all to orbit. On the other hand, if the APT mode is employed, all of the propellants analyzed can be used to achieve SSTO operation.

The ratios of payload to *wet* mass in Fig. 2 appear to indicate large advantages for the higher performing propellants, however a more relevant basis of comparison is the ratio of payload to *dry* mass, and this is shown in Fig. 3. Here you can see that CH_4/O_2 offers equal performance to the operationally much more cumbersome

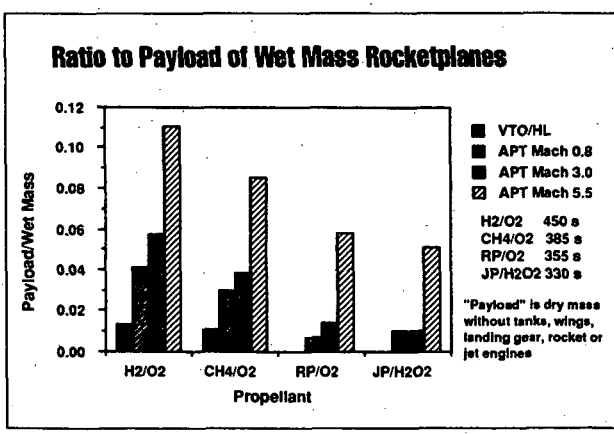

Figure 2: Ratio of payload to wet mass pf rocketplanes. It can be seen that for any propellant chosen all of the APT options outperform a VTO/HL.

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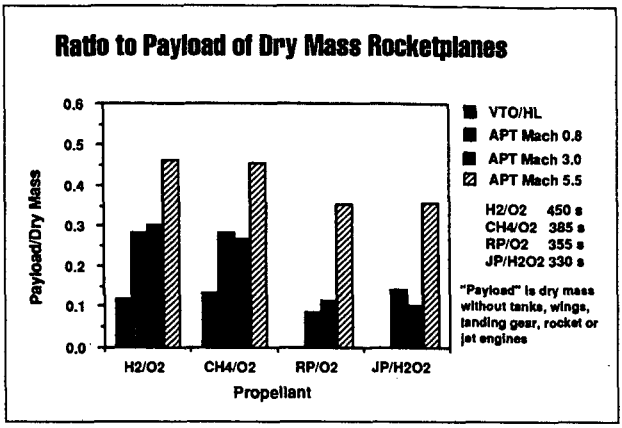

Figure 3: Ratio of payload to dry mass of rocketplanes. An APT spaceplane using JP-5/H_2O_2, firing its rocket engines from Mach 0.8 outperforms a H_2O_2 VTO/HL taking off from the ground.

H_2/O_2, and that both of these propellants more than double their payload when used in APT mode compared to their VTO/HL utilization. You can also see that RP/O_2 and JP-5/H_2O_2 offer about equal performance, with JP-5/H_2O_2 holding a slight edge for the Mach 0.8 (more or less pure rocketplane) incarnation. Interestingly, the data also shows that using airbreathing propulsion to go to Mach 3 offers little benefit over lighting the rocket engine in the subsonic. However if the airbreathers can be used to drive the APT up to Mach 5.5 (the upper limit of subsonic combustion ramjet operation), they more than pay for their mass penalty with reduced rocket ΔV, and the payload gains start to become impressive. Since the lower performing RP/O_2 and JP-5/H_2O_2 propellants are hurt more by having to deal with a large ΔV, they benefit more by airbreathing augmen-

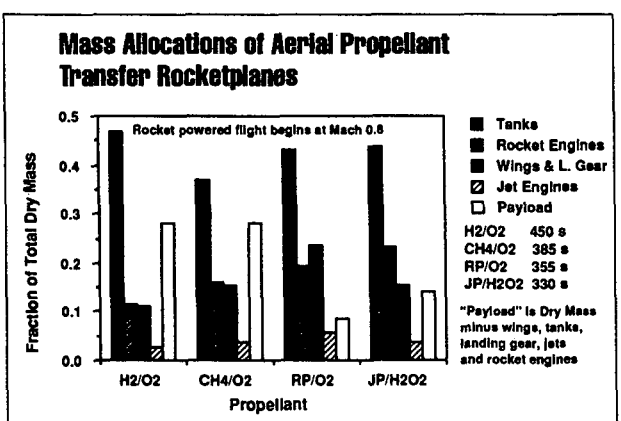

Figure 4: Dry mass allocations of Mach 0.8 takeoff rocketplanes. Tankage mass dominates the system.

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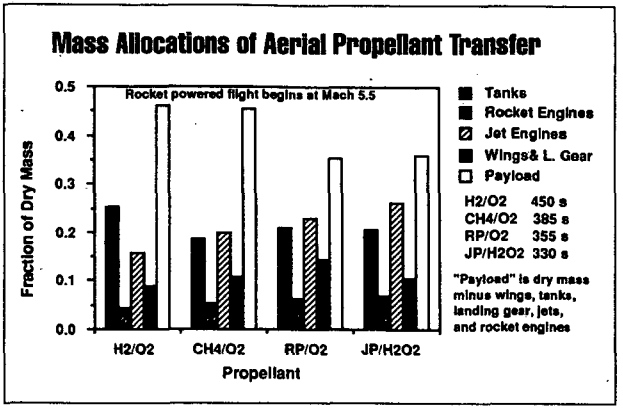

Figure 5: Dry mass allocations of Mach 5.5 takeoff rocketplanes. Payload delivery of all four propellant options are comparable.

tation; in the Mach 5.5 APT their payload delivery comes close to matching the CH_4/O_2 and H_2/O_2 options.

Dry mass allocations for the Mach 0.8 and Mach 5.5 APT systems are shown in Figs. 4 and 5. Both tankage and rocket engine masses drop sharply as we go from the Mach 0.8 to the Mach 5.5 versions, and while jet engine mass greatly increases there is still a net gain in payload. Interestingly, the tankage mass of the $JP\text{-}5/H_20_2$ system is slightly less than the H_2/O_2 system; it's carrying much more propellant but the propellant is much denser, resulting in rough equality. It should be noted, however, that no mass penalty was assumed in this analysis for insulating the hard cryogenic hydrogen, nor was any vehicle L/D penalty assumed for the non-optimal airframe shape that hydrogen use may require. If these effects are taken into account, hydrogen's performance evaluation could turn out to be much less favorable.

Therefore, to summarize, what we've shown is that the APT mode offers large improvements in payload delivery over the VTO/HL mode, so much so that an APT using low-performing non-cryogenic $JP\text{-}5/H_2O_2$ actually outperforms a VTO/HL using cryogenic H_2/O_2 (fig. 3). Within the APT family, the CH_4/O_2 system offers the highest performance, but if operational considerations such as the desire to avoid cryogens entirely or the need to employ off-the shelf engines in a near-term vehicle are taken into account, then $JP\text{-}5/H_2O_2$ or RP/O_2 both offer attractive options with real near-term capability.

The "Black-Horse" Study

During the winter of 1993-94, the U.S. Air Force's Phillips Laboratory conducted a contracted six-week study[3] with WJ Schafer Associates and Conceptual Research Corporation which developed the APT concept further. Since the emphasis was on maximizing the use of existing com-

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ponents and keeping the design simple, existing tankers, landing gear, and conventional technology were used as much as possible. For reasons which cannot be explained here, the rocketplane design was named "Black Horse."

The ground rules for the study were:

—Horizontal takeoff like an aircraft

—Two engines firing at takeoff

—Propellant transfer at 40,000-43,000 ft

—Hydrogen peroxide and jet fuel propellants

—Power-off landing

—LEO mission

—Throttling during propellant transfer

—Maximize use of existing facilities and support equipment

—Conservative design assumptions

Tanker Aircraft Selection

The first problem addressed in the study was how to do in-flight refueling of rocket propellants. In-flight refueling of jet aircraft is commonplace in the US Air Force and Navy today. Two systems are used: the Navy's probe and drogue system and the Air Force's boom refueling system. The probe and drogue system requires the pilot of the receiver aircraft to do all the work, and transfers about 250 gallons per minute. The boom system requires some cooperation between the boom operator and the receiver aircraft pilot, and can transfer 1,200 gallons per minute. The boom refueling system was selected for this design because of its high rate of propellant transfer. Two types of tankers use the boom system today: the KC-10 and KC-135. Of these, the KC-135 is smaller, less expensive, and more readily available. Of particular interest is the KC-135Q and KC-135T. These aircraft have an isolated fuel system, from which the tanker's own engines cannot draw. This will allow dedicated rocket propellant tankers to operate with only minor impact on the tanker's own systems. To avoid a costly development program, and the need to completely re-engineer the transfer system, it was decided that the propellant carried by the tanker serving Black Horse should be non-cryogenic and non-toxic.

Propellant Selection

There are only a few non-cryogenic oxidizers available: red fuming nitric acid, nitrogen tetroxide, and hydrogen peroxide are the obvious choices. Of these, only hydrogen peroxide is non-toxic. It has other advantages as well. It is very dense (1.432 g/cc in 98% concentration). It has a vapor pressure about one-ninth that of water. It is relatively inexpensive because it is an ordinary industrial chemical rather than a dedicated rocket propellant. Because it is a good coolant, ordinary JP-5 rather than expensive RP-1 can be used as the fuel. Although some special precautions must be taken to prevent it from decomposing in the presence of impurities, it is a stable molecule, and once those precautions have been taken it essentially handles like water. Detailed analysis of a hydrogen peroxide/jet fuel engine indicates the performance figures shown in Table

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Table 2. JP-5/H_2O_2 **Engine Performance**

	Climb Engine	*Takeoff Engine*
Chamber pressure	3000	3000 psia
Exit plane pressure	1.0	5.7 psia
Expansion ratio	240	70 —
Ideal I_{sp} (shifting equilibrium)	354	340 sec
Losses due to geometry	2.4	2.4 sec
Chemical Inefficiency Losses	1.8	1.0 sec
Viscous drag	7.8	6.6 sec
Energy release efficiency	6.7	7.3 sec
Delivered I_{sp} (in vacuum)	335	323 sec
Thrust	19930	19210 lb
Weight	310	280 lb

2 for a engine running with a mass mixture ratio of 7.30:1 (oxidizer:fuel). The two columns in Table 2 are for the two versions of the engine. (Black Horse carries seven engines: two for take-off and five for climb.) The "take-off" version is operable at sea level and permits the aircraft to take off, rendezvous with the tanker, and transfer propellant. The "climb" version is only operable at tanker altitude or above, and is optimized for the climb to space.

The advantages of the Black Horse aerial propellant transfer concept are threefold. First, the propellants are at a very high density—1.32 g/cc of propellant at the mixture ratio given. This leads to a smaller vehicle and the capability of transferring up to 155,000 pounds of hydrogen peroxide from the tanker to the receiver. Second, they are non-cryogenic, so that the modifications to the KC-135Q or KC-135T model tanker will be minimal. Finally, the mixture ratio is unusually high. At a mixture ratio of 7.30 to 1, 88% of the benefits of aerial propellant transfer is available if one propellant only is transferred. This helps with keeping the operation simple and removes some safety concerns with simultaneous propellant transfer.

Mission Profile

The Black Horse mission profile begins with a takeoff from a conventional runway using the two takeoff rocket engines for thrust. The aircraft is loaded with all the fuel it needs for the climb from the tanker to orbit. It also has fuel and oxidizer aboard sufficient for 15 minutes of atmospheric flight. The total weight of the vehicle at takeoff is about 50,000 pounds, but by the time it achieves tanker rendezvous at 43,000 feet and 0.85 Mach number its weight has dropped to about 38,000 pounds. When the aircraft meets the tanker it takes on about 147,000 pounds of hydrogen peroxide. It then disconnects from the tanker and climbs to space. As it inserts into orbit, its weight has dropped to about 16,500 pounds. After performing its orbital mission, the aircraft reenters and then glides to a normal landing at a runway. A

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drawing of the Black Horse vehicle is shown in Fig. 6.

Weights

The weight buildup of a rocketplane vehicle will determine whether it is possible to enclose the required volume of propellant in an aircraft that weighs little enough to permit that propellant to launch it into space. Table 3 indicates the assumptions for each of the major weight components and the total weight of the Black Horse system. The basic assumptions made for the vehicle were to apply conventional structural technology by forming the blended wing/body of the aircraft from ordinary aluminum alloy. The thermal protection system technology deemed suitable for this application is carbon/silica carbide for the nose cap, DuraTABI for broad areas on the lower surface, and a lightweight blanket insulation for the upper surface. The crew cabin accommodations are austere, as in the U-2 reconnaissance aircraft.

Design Considerations

Unlike most spaceplane designs, Black Horse needs to have a particularly high subsonic lift to drag ratio. This is necessary for two reasons. First, the requirement to fly in the atmosphere on the rocket engine impels the designer to minimize thrust required, so that the rocket propellant load at takeoff remains small. Second, the vehicle's gross weight changes by a factor of about 4.5 during propellant transfer. The maneuver will be very difficult for the pilot to fly if the aircraft does not have a good

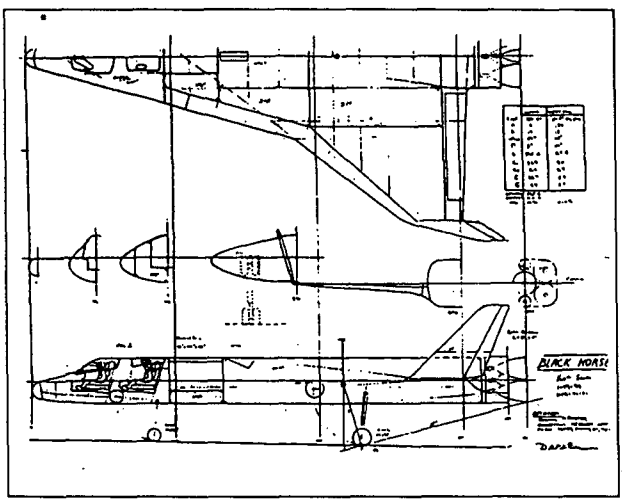

Figure 6: Black Horse, a single stage to orbit vehicle using aerial propellant transfer. With a wing span of 39.5 ft and a length of 57.5 ft, the aircraft is comparable in size to a F-16 fighter. (Drawing by Dan Raymer)

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Table 3. Black Horse Weight Breakdown (pounds)

Structures Group	6,686
Wing	1,572
Vertical tail	739
Fuselage	2,924
Main landing gear	916
Nose landing gear	243
Engine mounts	292
Propulsion Group	3,091
Engines	2,120
Fuel system	971
Equipment Group	1,181
Flight controls	372
Instruments	142
Avionics	567
Furnishings	100
Mission-specific Group	4,000
Reaction controls	400
Life support	800
TPS	2,800
Total Empty Weight	14,958
Load Group	33,494
Payload	1,000
Crew	440
Propellant	32,054
Takeoff gross weight	48,452
Tanker rendezvous weight	37,380
Oxidizer transfer	146,870
Gross light-off weight	184,250

cruise lift-to-drag ratio. To accomplish these objectives, the Black Horse aircraft features a highly blended design to maximize volume. The double-delta platform was adopted to provide minimal change of the aerodynamic center over a broad speed range, and also to provide a large strake to hold fuel and oxidizer so that the center of gravity does not move as the propellant is consumed.

The overall wing area is 780 square feet. The wing loading is sufficiently low that no lift devices such as flaps or slats should be needed for takeoff or landing, especially with the enormous thrust available from the rocket engine. The low wing loading also helps a lot in moderating the thermal environment during reentry.

The "Black Colt" Study

Another study of a somewhat dif-

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ferent APT concept was done at Martin Marietta during January through May 1994, this one of a near-term suborbital X-Plane that could serve as a demonstration vehicle for the APT concept. Because the vehicle was about half the size of Black Horse, it was decided to call it "Black Colt." A flying Black Colt to half orbital velocity, with the 1000 lb payload then being delivered to orbit by means of a Star 48V upper stage. By adopting this strategy, it was found feasible to design a reusable satellite delivery system with a wet mass fraction of 0.78, which represents a large relaxation in

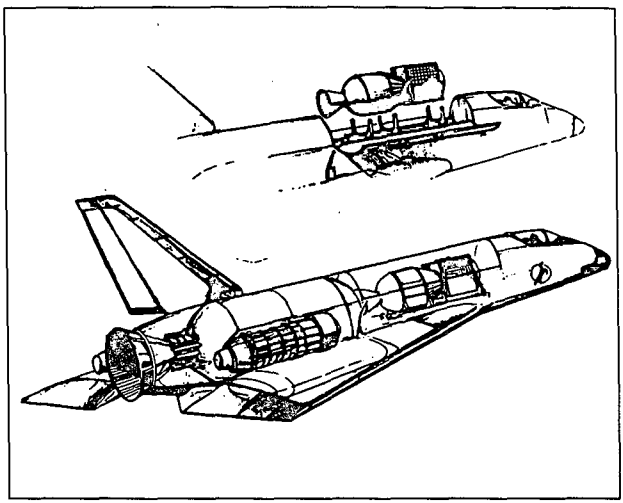

Figure 7: Black Colt flies on a suborbital trajectory to Mach 12 and 80 nautical mile altitude. The payload is then delivered to orbit by a Star 48V solid rocket, after which orbit circulation is done by the satellite's thrusters.

drawing of this vehicle is shown in Fig. 7.

The spirit of Black Colt was to design something that can be built and flown today. Thus, an existing NK-31 RP/O_2 rocket engine was chosen for primary propulsion, with two Garrett F125 turbofans used for takeoff, loiter during aerial propellant transfer, and landing propulsion. Also, rather than push for the very high performance required to achieve true SSTO operation, it was decided to settle for only requirements relative to the 0.92 needed for Black Horse. Since the expended Star 48V only costs $1.4 million and allows Black Colt to deliver a larger payload than a $12 million Pegasus, the trade was considered quite favorable. The Mach 12 reentry required of Black Colt is also much less demanding on the technology of reusable thermal protection systems than the Mach 25 reentry of any true SSTO.

The NK-31 burns oxygen and kero-

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sene at a mixture ratio of 2.6:1. Thus about 19,000 lbs of kerosene are required to burn with the oxygen. The remaining 2,000 lbs are used for climb to the tanker and for 30 minutes of subsonic powered flight after reentry. When fully fueled with kerosene and carrying no LOx or payload, the vehicle has a fuel mass fraction of 0.53, with a subsonic L/D of 9, this gives it a subsonic self-ferry cruise range of about 3,300 nautical miles.

While the Black Colt's F125 engines have a sea level static thrust of 10,000 lbs each, thrust falls off to 6,300 lbs each at 20,000 ft and Mach 0.8. Since the vehicle has a subsonic L/D of about 9, implying a total thrust requirement of 10,500 lb when fully loaded, this limits the refueling altitude to about 23,000 ft if the refueling is to be done under jet engine power alone.

Rather than modify the fuel tanks of a KC-135 to carry LOx, it was felt that the simplest way to enable aerial LOx transfer would be to carry a dedicated LOx tank within the fuselage of any suitable large subsonic aircraft. Tank trucks of the Liquid Air company currently carry tanks with 70,000 lb LOx capacity, greater than that required for Black Colt. Such tanks have boiloff rates of less than 0.25% per day, and with a diameter of less than 8 ft, could be installed within many candidate aircraft. This leaves a cryogenic refueling boom as the primary refueling related development item. While transferring LOx at altitude has been raised by some as a safety concern, in many respects such transfer is safer than handling LOx on the ground, as any LOx spills will be instantly dissipated to the environment and there is no water around to freeze things up.

A cost estimate was done on the Black Colt program. Current estimates indicate that such a vehicle could be up and flying within three years of program start for a total cost of less than $100 million.

Flight Test

Unlike most space vehicles, it will be possible to test the aircraft proposed here in a conventional flight test environment. No special range requirements beyond what is conventionally available at, for example, Edwards AFB should be required. Because there are aviators aboard the vehicle, no destruct package is needed. Aside from storage areas for the new propellant, it should not prove necessary to construct any new facilities for any phase of this program.

The flight test program could begin in a conventional build-up fashion, starting with taxi and ground tests, first flight, performance, and flying qualities testing. This phase of the program would emphasize handling qualities while connected to the tanker boom, because the oxidizer transfer could as much as quadruple the weight of the aircraft when it takes place. Once the flight control system has been qualified, transfer of steadily increasing amounts of oxidizer would support envelope expansion and flight to increased altitudes and airspeeds. Exoatmospheric flight and reentry could be investigated, and the operational envelope of the

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Table 4. Black Colt Weight Breakdown (pounds)

Turbojets (2 F125's installed, 10klbf each)	3,458
Rocket Engine (1 NK-31, 90 klbf)	1,540
Structure	3,200
Wings	2,490
Propellant Tanks	500
Landing Gear	1,621
Thermal Protection	1,760
Pressurization system	50
RCS	150
Avionics	450
Contingency (20%)	3,043
Total Dry Weight	18,263
Kerosene	21,000
Oxygen	50,000
Star 48V	4,840
Payload	1,000
Total Gross Weight	95,103

thermal protection system could be determined. The capability of the system to perform long distance ballistic transfers (in the case of Black Horse, to anywhere on Earth within one hour) could be demonstrated. Loading the aircraft with fuel and oxidizer, up to the maximum takeoff weight, could also permit exoatmospheric flight without propellant transfer. The ballistic ferry range of the Black Horse aircraft under these conditions is about 3,200 nautical miles, allowing for some aerodynamic range extension at the end of the trajectory.

An orbital flight attempt would follow the envelope expansion phase. Investigation of on-orbit flying qualities could proceed at this point, as well as an experimental determination of reentry cross range. One sub-phase of the orbital flight test program of particular interest would be on-orbit propellant transfer. If the aircraft were completely refueled in low-Earth orbit, it would have enough ΔV to visit anywhere in cislunar space, such as geostationary orbits, or to perform multiple plane changes and visit many different points on a single mission. Reentry from increased altitudes and entry speeds could be tested, yielding an assessment of the capability of a high temperature reentry capability in realistic conditions.

Military and Civilian Applications

Beyond their application as SSTO payload delivery systems, there are many potential uses for Black Horse/Black Colt type APT spaceplanes. With performance requirements con-

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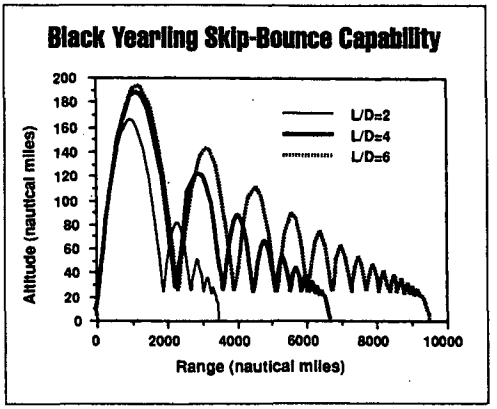

Figure 8: Atmospheric bounce capability of an enhanced Black Colt ("Black Yearling") aerial propellant transfer spaceplane. The vehicle in question is propelled by two NK-31 rocket engines and two F404 turbofans. It has a dry mass of 22,000 lbs and carries 120,000 lbs of propellant.

siderably less than that needed for SSTO flight, such vehicles could fly from any point on Earth to any other point in less than an hour, with most of the flight being exoatmospheric. In the NASA arena, such APT vehicles flying routinely in a suborbital mode could be used as hypersonic test vehicles, medium duration (15 minutes per flight) zero gravity labs, ionospheric/thermospheric sounding vehicles, and even short duration astronomy platforms. Within the military sphere, APT vehicles could be used for a number of interesting applications, many of which are enhanced by the ability of an APT to bounce out of the atmosphere after an initial reentry. This would allow it to drop in over a designated area from space

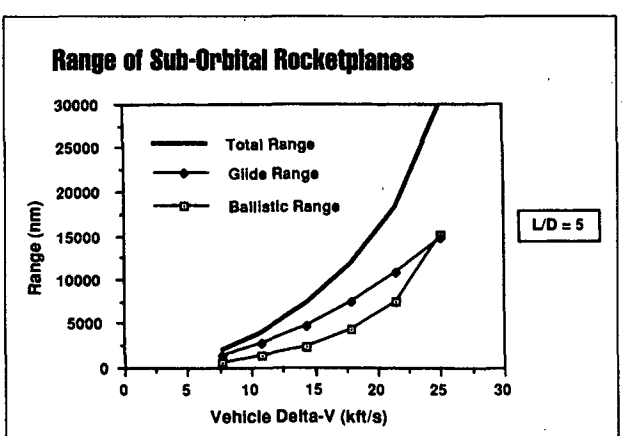

Figure 9: Ballistic and glide range capability of suborbital rocketplanes.

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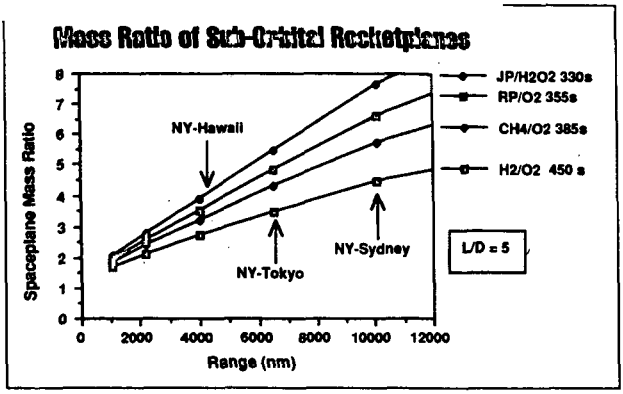

Figure 10: Mass ratio for suborbital rocketplanes utilizing various propellants.

at hypersonic (Mach 10-20) velocities, release a payload, and then pop out of the atmosphere and get away to space (Fig. 8). Within the civil sector, such vehicles could be used for fast passenger transport, fast package delivery, prestige business travel, space barnstorming rides, and as a vacuum or zero gravity industrial research platform.

It should be noted that most of the range of suborbital vehicles is provided by aerodynamic lift after reentry, not by the ballistic hop itself (Fig. 9). This is the fundamental reason why for all applications involving surface-to-surface distance capability, winged vehicles such as the APT offer much greater performance potential than strictly ballistic vehicles of the VTO/VL type. It can also be seen (Fig. 10) that the mass ratios required for such vehicles to achieve substantially global range for surface to surface travel on Earth are much less than those required for SSTO flight, which means that the payloads delivered can be much greater. It may be objected that while a CH_4/O_2 APT might only require a mass ratio of four to travel from New York to Tokyo, which is clearly achievable in the engineering sense, a subsonic airliner can perform the same feat with a mass ratio of two, and thus despite its (much) faster flight time, the APT spaceplane would fail economically. This argument neglects the fact that almost 80% of the propellant of the CH_4/O_2 spaceplane is LOx, which sells for $0.05/lb, compared to $0.20/lb for jet fuel. When the difference in the per pound price of propellant is taken into account, the spaceplane's fuel economy is quite competitive.

A Speculative Idea

Beyond their baseline mode of operation, certain speculative operational modes exist that could significantly enhance the capability of APT vehicles in the future.

Consider the case where we have two Black Horse type vehicles, each using JP-5/H_2O_2 with an I_{sp} of 335 s. The vehicles have a dry weight of 15,000 lb and a propellant load of 180,000 lb, which assuming a required ΔV to orbit of 27 kft/s, allows them to deliver 1,000 lb to LEO. Now,

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let's say that we fly the two of them off together, accelerating them jointly not to orbit, but rather to a suborbital trajectory with a velocity of 18.5 kft/s. The two spaceplanes are now outside the atmosphere, in free fall (i.e. zero gravity) in the immediate vicinity of each other. Let's say we now bring the two together and extend a refueling boom, allowing the 20,000 lb of residual propellant from one to be transferred to the other. The two then separate, the empty vehicle to return to Earth, the enriched vehicle to ascend to orbit with a payload of 12,000 lbs. Without any new hardware, the orbital delivery capability of the system can be increased by a factor of 12.

Such a non-material enhancement by teamwork would allow even an APT spaceplane that was designed for suborbital flight to achieve orbit. Or put another way, let's say that it turned out after the construction was done that the actual Black Horse dry weight came in not at 15,000 lb, but at 24,000 lb, a 60% mass growth over the estimate. The vehicle would now only be capable of suborbital flight to 23 kft/s. However, if two such vehicles were flown, performed a suborbital propellant transfer at 15.5 kft/s, the enriched vehicle would be able to make orbit with a 1000 lb payload. Since the propellants being transferred are non-cryogenic, such a suborbital zero-*g* propellant transfer could be done using bladders. If the APT in question used LOx for its oxidizer, the transfer would require a weak gravity field, which could be created by both vehicles firing their RCS systems continually during the transfer.

The plan certainly sounds incredible, and to be frank, we don't expect such maneuvers to be done anytime soon, but it's not impossible. On a suborbital trajectory with a velocity of 16 kft/s and a 120 nautical mile apogee, the vehicles in question will be out of Earth's atmosphere for about six minutes. The actual propellant transfer can be done in less than two minutes. With sufficient training, good pilots could eventually do the job.

The idea of refueling an airplane in flight must have seemed bizarre to anyone witnessing the Wright brothers first flights. By the 1920s it had been demonstrated, and today it is done routinely. Doing it on the way to space, and in space itself are just the next steps up the ladder.

Conclusion

What we've shown is that using in-flight propellant transfer to reduce the ΔV needed to fly to space makes it possible for a fighter-sized aircraft to achieve orbit. Furthermore, such an aerial propellant transfer spaceplane outperforms alternative vertical and horizontal takeoff SSTO concepts, and offers a much greater range of potential alternative suborbital applications as well. If such a flight mode is used, a completely non-cryogenic SSTO employing non-toxic rocket propulsion based on H_2O_2 and JP-5 is feasible, and even higher performing systems can be built using soft cryogenic CH_4/O_2 propulsion. Perhaps most importantly, the development of an aerial propellant trans-

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fer X-plane spaceplane could be done quickly and cheaply and would permit a variety of revolutionary military and civil capabilities to be demonstrated. Why most importantly? The answer is this:

If the real space age is ever going to be opened up, we will need to have a market for rocket vehicle technology that supports the manufacture of spacecraft components not in lots of ones or twos, but in hundreds or thousands or tens of thousands. If travel to orbit is ever to be as cheap as air travel, we will need a worldwide infrastructure that supports not hundreds of flights per year, but hundreds of flights per day. The only market that can support that kind of development is global long-distance surface to surface passenger travel—like it or not, a lot more people want to go to Tahiti than want to go to orbit. If you want to serve that market, you want to use winged rocketplanes, not vertical takeoff vehicles, because trillions of dollars worth of infrastructure is available all over the world—in the form of existing airports and surrounding facilities—to support their operation. Now it won't happen all at once, and for the same reason that military and then postal aircraft preceded passenger aircraft, military and fast package delivery rocketplanes will precede passenger rocketplanes. But once it does happen, once thousands of rocketplanes are crisscrossing the globe daily, serving business and vacation travelers from New York to Sydney, it won't be to hard to set some of them aside to establish passenger lines to orbit. In fact it won't be too hard to specially outfit a few to be refueled on orbit for expeditions to the Moon or Mars.

That's why Black Horse is an airplane worth fighting for.

Acknowledgments

The authors wish to acknowledge the important work done by Dan Raymer and the W. J. Schafer team of William Nurick, Frank Kirby, Ed Nielsen, Robert O'Leary, Rett Benedict, and Ray Walsh in developing the Black Horse design concept. We also wish to acknowledge the contributions in helping to analyze the Black Colt performed by the Martin Marietta team of Sid Early, Jim Greenwood, Grady Romine, Robert Humphries, Greg Velasquez, Lars Onsager, Elizabeth Sholes, Ann Palen, and Jeff Schnackel. Useful comments and suggestions on Black Colt from Burt Rutan, of Scaled Composites and Lt. Col. Steve Brandt and Lt. Col. Doug Beason of the U.S. Air Force Academy are also gratefully acknowledged. The drawings shown in figs. 1 and 7 were done by Robert Murray, of Martin Marietta. The drawing of Black Horse shown in fig. 6 was done by Dan Raymer. ■

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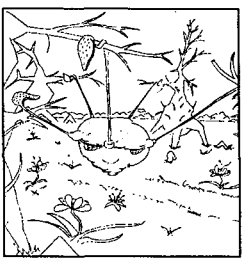
From The Travel Diary of Braxton Montague Shew IV



The Shree of Planet Dzehn

My Dear Mater:

Yesterday, the good ship and true, *ASD Albert*, nosed into Port Dtchiteh circling the planet of Dzhehn; and I and my faithful traveling companions, Umberto from Milano, and Mbwurto from kwa-Swazi, shuttled planetside, where we immediately set forth into that great nature preserve, justly famed throughout Vermillion Sector: the sprawling jungle known to the locals as "Dtartsanadah." The Squatting Thorntrees were every bit as bizzare as their pictures had suggested; and the *gimmi-gimmi* plants, which resemble an outstretched Dzhenian hand, waggled their colorful petals in the breeze. Our guide, Bpirt, then showed us the most remarkable creature in Dtartsanadah Jungle: namely, the *shrii*, the creature in the known galaxy to begin life as a plant and mature into an animal. I have rendered the beast in the enclosed sketch. It's five-fold radial symmetry is marked by alternating eye-spots and tentacles, known as *hlahstos*. When filled with a sudden rush of fluid, these extremities extend and wrap themselves around nearby branches. Suckers on the lips penetrate the tree and draw out the sap. The *shrii* moves by withdrawing a *hlahtso* or two, swinging pendulum-like on the others and fastening onto a new tree with the free tentacles, a process the natives call *dtarzaning*. Before moving on, the *shrii* drops seeds/eggs through the orifice on its bottom. In its larva and pupa stages, the *shrii* is a ground plant called an *uurn*, respectively the "egg"—and "flowering"—*uurn*. As it matures, the petals fold up and harden into the carapace, and the stamens become the tentacles, which then reach up and secure a perch on the canopy. It took many years of patient research before Dzhenian naturalists realized that the *shrii* and the *uurn* were two forms of the same creature. The decisive observation was, of course, that the egg-*uurn* seldom fell far from the *shrii*.

Love as always,

BRAX

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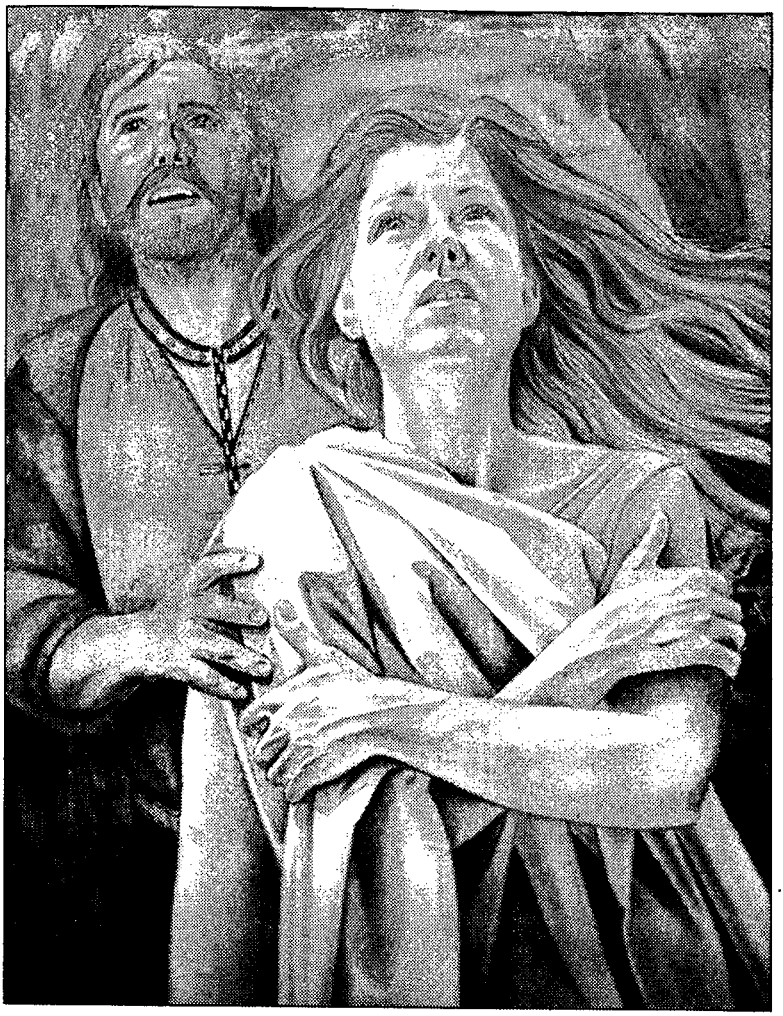

Maya Kaathryn Bohnhoff

AS THE ANGELS IN HEAVEN

One culture may see another's ways as so perverted that it's hard to imagine one evolving into the other—but sometimes it's all too easy. . . .

Illustration by Steve Cavallo

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From the moment they met, eye to eye, hands clasped over the same book, it was inevitable that they should fall completely in love and having done that, that they should marry. It was an archaeology book, which was fitting; both had master's degrees in the subject and both were employed by Archaetech, one of the world's largest private archaeological corporations. It was a match made in heaven; they were intellectually equal, philosophical aligned, and theologically unified. They cried at the same movies, were inspired by the same authors, angered by the same injustices. They were, in a word, compatible. And more.

Archaetech was corporately pleased by their decision to wed; husband and wife teams were preferred for the long term digs. It was a perfect situation.

Birch Asbury was a happy man. He congratulated himself almost as often as his many friends did. In a matter of mere hours, he and Meli Bocamp would be married and on their way to their first long term dig. They would live together, work together, make discoveries together and bicker over technique and the significance of artifacts. He smiled.

"Daydreaming, eh?" His closest male friend, Clay Munsi-Couric, sat down across from him at the table they shared in the Company Commons. Clay grinned and nudged Birch's arm, just missing the two cups of steaming coffee that had exited the wall replicator seconds before. "Let me guess—fantasizing about your first dig together, eh?"

"As a matter of fact, yes, I was."

Clay's grin widened. "Kidding, right?"

Birch sipped his coffee and wrinkled his forehead. "Why should I be kidding?"

Clay leaned closer to his friend across the table and lowered his voice. "Come on. Admit it, old bud. Don't you at least want to drink a toast to the end of chastity?" He raised his cup and winked.

It was a slight gesture and one Birch nearly missed since his own eyes were dodging away. He blushed, knowing that implied a certain falsity, and wondered if he should bother with a denial. Truth was, he had given some thought to that aspect of his future: An end to chastity. A whole new area of life to explore; a whole new set of rights and prerogatives. But his feelings when he contemplated this were far from salacious. Birch Asbury was frankly uncomfortable with the subject of sex.

He was not a prude. He didn't deny his sexuality. There were those who did, of course, with varying degrees of success and/or honesty, but he was not one of them. He was probably no more ashamed of his sexuality than Clay was. Not really. What bothered Birch was the particular bent it took.

So now, to cover his mild embarrassment, Birch grinned and raised his coffee cup. "Guilty."

Clay touched the cup with his own. "Then here's to the end of chastity."

Meli Bocamp was toasting, too, at that moment, in a patio bistro on the massive, gleaming eastern flank of

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Archaetech's corporate headquarters. Her two closest girlfriends around her, she lifted a glass of alcohol-free champagne and drank to her future.

"So tell," demanded Cari Munsi-Couri, dark eyes dancing. "What's the honeymoon to be?"

"Indian sub-continent. The caves at Ajanta."

Golden-haired Roella nodded vigorously. "And paid for by Corporate, no less."

"And why not?" Meli asked. "Are we not, after all, doing the work of the Company? Preserving our ancestors' treasures for our children?" Meli flushed at her own mention of children, without really knowing why. But neither Cari nor Roella noticed, and the celebratory lunch continued around a rousing discussion of the halcyon days of the Gupta Dynasty.

Birch Asbury adjusted his collar and reflected that he was not nearly so nervous as he was eager. Eager to get through the brief ceremony, eager to board the international shuttle to Nagpur, eager to meet his new colleagues and begin his new life with his new partner. At Ajanta he would bury himself in the heady atmosphere of discovery, wallow in the contentment of cultural minutiae—with Meli at his side.

Best man Clay interrupted his maunderings by tucking a red paisley scarf into his suit pocket. "So, old bud, have you found a cleaning lady yet?"

Birch fussed with the kerchief. "Uh, no, actually, I haven't. Haven't had time."

"You're leaving for India tomorrow morning. It's a little late to do it now."

"Honestly, I haven't given it much thought."

Clay gave him a wry smirk. "Bashful boy. You haven't even interviewed anybody, have you?"

"What would be the point? I'm on my way to a dig, for God's sake. I don't suppose many women would consider a remote base camp on the Deccan plateau a plumb position. I thought I'd . . . wait until we got to Nagpur."

Clay nodded approval. "An exotic, dark-eyed beauty. I can see the appeal."

"Honestly, Clay. That's borderline racism."

"So sue me for being politically incorrect." He watched Birch pick at the inoffensive scarf for a moment more. "You really are bashful, aren't you? Good grief, Birch, we're talking about filling a domestic position. Has Meli interviewed anybody?"

Birch kept his grimace to a mere twitch. "She says she's not interested."

Clay shook his head. "That's women for you. Cari tells me most of our married lady-friends have the same attitude. How do they do it? Must be that extra X chromosome."

"It's time," Birch said, then checked his watch.

Clay patted his shoulder. "Look, you'll be in town tonight. Why don't I introduce you to Sonia?"

"Sonia?"

"My cleaning lady."

"Oh, right. Thank you very much, Clay. I appreciate it, really. But, well

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we've got a lot of packing to do and I couldn't just run off and saddle Meli with it."

"It won't take long."

"No, really."

"Birch, you'll be a married man in less than half an hour. You're entitled. Besides, you're my best friend, next to Cari. I helped you get the job at Archaetech; I guess that means I'm indirectly responsible for your meeting Meli, right? We've shared a lot of important things in our lives. I think it would be kind of, well, special to share this."

Birch didn't allow his face to betray shock. He was getting quite good at masking his thoughts and feelings, and it worried him. He smiled in return. "It's a wonderful gesture, Clay. Thanks. But, look, your—Sonia—might not like you offering her services—"

"She wouldn't mind at all. Trust me. For one thing, she'd jump at the chance to make a better living."

"Assuming she even has room for another client."

Clay grinned. "She's an exclusive. And she likes me. A lot." He winked.

"No. Thank you. I'll take care of the domestic situation when I get to India."

"Will you?"

Birch gave Clay no time to say more. "I'm getting married now," he said, and slipped from the room.

"Beautiful ceremony!" enthused Cari, and her eyes brimmed with tears, because some people will always cry at weddings. "It reminded me of mine and Clay's. Mom cried, Dad cried, everybody cried."

"I didn't," said Roella. "I don't see any reason to cry at weddings. They're supposed to be happy occasions. Not like before Equilibrium, when it was tantamount to being sold into slavery."

"I *am* happy," Cari assured her. "I'm happy that Meli and Birch are finally embarking on a life together. Just like the minister said: 'as the angels in heaven.' Meli, believe me, marriage is heaven. Here's your makeup kit." She handed that item to Meli, who tucked it into her carryall. "Just imagine: India. Tomorrow. You and Birch and that heavenly dig. Clay and I went to Peru on our honeymoon. Nice, but too hot until we got into the High Andes. But then . . . oh, the ruins!"

"I'm not sure I want to marry within my profession," mused Roella. "Seems to me the proximity effect could be deadly."

"It hasn't been for Clay and me." Cari patted her friend's lace-covered shoulder. "Find the right man or woman and you'll see it makes all the difference in the world. Besides, you create your own environment in a marriage. And your own distractions." She shifted her shoulders suggestively and Roella smiled.

"Oh, you hot-blooded older women," she said. "How about you, Meli? Are you going to create your own distractions?"

Meli, barely existing on the same plane, came to the sound of her name. "Huh?" she said.

"I think Roella wants to know if you've hired a handyman."

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Meli shoved a pair of camp-boots deep into her suitcase and shook her head. "No, I haven't. And what would Roella know about handymen?"

Roella blushed to the pale roots of her hair. "Well, Cari has one. I've heard her talk about him. Hell, my mother has one. And I'm of a marriageable age, after all. I suppose I ought to start thinking about these things. It's all right to think about it, you know."

Cari laughed, apparently delighted by the younger woman's defensiveness. "Of course it's all right to think about it. As long as that's all you do."

"Good Lord, Cari. Of course that's all I do! But even a virgin has her fantasies." She shrugged. "I'm curious, that's all. Who wouldn't be? It's nothing to call church about. I've heard Mom and Sis comparing notes . . . Sis had a semi-regular guy for a while. Said she started feeling like she had to use him just because he was there. Then she realized she wasn't getting anything out of it and fired him."

"Well," said Cari, "to each her own. So, Mel-Mel, you're not going to hire a man. Somehow, that doesn't surprise me. What about Birch?"

Meli flinched mentally. "What about Birch?"

"Has he got himself a squeeze, yet?"

Roella coughed. "Cari Munsi-Couric! Your language! That's so-so derogatory, so sexist."

"It's just a colloquialism, Roella. You should hear what they call us—'little men,' 'neuters,' 'bergs' —that's short for 'iceberg.' Sonia calls me Eunice right to my face."

"Sonia?"

"Clay's cleaning lady. She's not being disrespectful, really. It's just a joke between the two of us."

"A joke?" Roella shook her head. "I don't get it."

"Eunice—sounds like Eunuch?"

"Oh. Oh. I get it. But you're not a Eunuch at all. I mean, you've got a guy."

"Yeah, she calls him my 'ice-pick.' Cute, huh? Point is, I'm neuter as far as Clay's concerned. Sonia just doesn't 'get it.' I mean, her whole world is sex, right? Love isn't something she relates to. Not the kind of love Clay and I have. I feel sorry for her."

Meli paused in her packing and studied Cari's pensive face. "You actually socialize with her? Doesn't that feel . . . well, strange?"

Cari and Roella were both looking at her, brows knit. "That's a weird question," Cari said. "Why should it feel strange? Clay has a lusty sex drive. It has to go somewhere. Sonia's clean—I insisted he have her checked, of course—and she's exclusive to him. As a matter of fact, she'd just registered with the agency when he hired her. Straight out of high school. A virgin. Clean slate. And I like her. In fact, if we decide to have children, she'll probably be the carrier."

Meli frowned, pushing the flutter of unease back to the pit of her stomach, pushing another pair of shoes into her suitcase, pushing any further weird questions to the back of her mind.

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Roella shook her head. "I don't understand that. I mean, why would a girl not want to go to college? Why wouldn't she want a career and marriage? Have you ever asked Sonia that?"

"Honey, Sonia has a career. She's a Sexual Relief Specialist. And yes, I did ask her, just out of curiosity. She's from a poor family—a dysfunctional family, as it happens—she did poorly in school, no head for academics or trades, and she liked sex. She said staying a virgin through high school was the hardest thing she ever did."

"Geez," breathed Roella. "I thought . . . with the Equilibrium and all. . . . "

"Not everybody can live by the same code, Ro. For which we should be thankful. If there weren't people like Sonia around to take care of a man's needs, where would we be?"

"Back in the dark ages, I imagine," said Roella. "I see your point."

Cari shrugged. "So, Sonia's in social service. She's happy. Clay's happy. I'm happy. She's a gorgeous girl—healthy, nice disposition. She'll be a great carrier for our kids."

"But if she has a baby," Meli asked. "How do you know it's yours? I mean, how do you know the pregnancy is the result of the implantation of your egg and Clay's sperm and not, well, the result of their having intercourse while she's on the fertility program?"

"Meli, I trust Clay. After all, he's my husband. He loves me."

There was no doubt in Cari's voice, no uncertainty in her face. She and Clay had that kind of relationship—a perfect relationship, Meli would have said. A relationship based on love, respect, trust, equality, intellectual compatibility and a passionate commitment to mutual growth and happiness. She and Birch had all that, she knew, if not the level of openness Clay and Cari enjoyed. The most she'd ever said to Birch about her sexual inclinations was that she wasn't particularly concerned about them. Which was only partially true. Until she'd met Birch, her sexuality had been a non-issue. Now, it was an issue she studiously and ambivalently avoided. She envied Cari and Clay their frankness, their openness.

No. No, she didn't. She wanted to envy them and did not. And that disturbed her.

Ajanta was an amazement. Sweeping along the rocky basalt face of a Deccan river gorge, the twenty-eight hand-hewn temple caves bore mute but eloquent testimony to the ingenuity and perseverance of humanity. Dating from India's Golden Age in the tenth and eleventh centuries after the Advent of the Buddha, the religious shrines were begun during the reign of Emperor Harisena. They were unfinished when a sweeping return to Hinduism, followed by an advance to Islam, left them to lie forgotten until 1819, when a British army detachment stumbled over them in the colonial darkness.

After over a century of dithering and dickering, the disposition of the caves fell to the Global Tribunal which, in the interest of India's heritage, hired Archaetech to restore the temples to their original glory.

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Such was the Asbury-Bocamp's happy duty—to bring Ajanta back to life. The work consumed them from the moment they arrived; the magnificance of the paintings, the incredible scope and detail of the statues and carvings, the majesty of the hand-hewn chambers. It was at once overwhelming and satisfying.

It was their special pleasure to rise before their colleagues and visit a favorite cave, sitting in shared and meditative silence before its major shrine.

It was a shrine of love, Meli thought, though disconcertingly medieval in its vision of that emotion. The central group of statues were made up of a woman (Queen Hariti) and a man (Hariti's husband, Panchika) and their many children. They sat, looking out at the worshipful from their basalt thrones, serene, lovely, blissful, while overhead a painted medallion with all the rich color and pattern of a Persian carpet completed their pavilion. At each corner of the medallion's square frame sat a Happy Couple. That's what everyone called them, with varying degrees of sarcasm. Half-naked and entwined in modest intimacy, they gazed eternally at each other with dark, adoring eyes and smiles of secret bliss.

Meli called them, "The Happy Couples" with no sarcasm at all. Except for their implicit sensuality, they reminded her of Birch and herself. She shared that with no one—not even Birch—but she found herself less disturbed by the couples with every visit.

Sometimes she and Birch would paint word pictures of the Buddhist monks and bhikkus going about their ardent tasks—the blessed Holy Men, depicting the beauties of their Faith with absolute delight. Meli could almost see them, working among the statues and frescoes, scurrying along the corridors, climbing the steep stone paths from the gorge below. Much like their archaeological team, she thought, but with one important difference.

"Do you ever wonder," she asked one morning as they stepped out of Cave Two at the summons of the breakfast bell, "what it would be like to create something instead of merely handling creation after the fact?"

They stood in the slanting rays of morning, gazing down into the shadowy, inviting reaches of the river gorge. "I do," said Birch. "I do wonder."

That was the morning of the day Clay and Cari arrived. A surprise. A pleasant surprise, all in all, but one that raised in Meli Asbury-Bocamp the specter of her previous ambivalence. Clay had brought Sonia with him.

She was nice, as Cari had said, if a little vague. She giggled a lot. Clay introduced her around, taking special care to bring her face to face with Birch. Meli felt something insidious and alien coil around her heart.

"I feel like a crumb-cake not telling you we were coming over," Cari told her, drawing her aside to the stone fireplace of the camp's main lodge. It was a real fireplace, but contained no real fire. A Hughes Friction Coil produced the heat; the flames were holographic. "We wangled the assignment

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a month after you left. We just missed you so much, we couldn't stand it."

"We missed you, too," Meli said, watching Sonia and Clay and Birch chat with a couple of their new camp friends.

"Are you sure?" Cari laughed. "That wasn't very convincing."

Meli gave her friend her full attention then—somewhat guiltily. "I'm sorry, Cari. Of course I'm sure."

The other woman put a hand on her arm. "I hope you don't mind Clay snatching Birch like that. He's missed him a lot. Besides, I think he has his own agenda where Birch is concerned. He's convinced your husband is. . . ."

"Is what?"

"Well, too shy for his own good. About sex, I mean. It may be fairly easy for a woman to do without relief—well, some women—" She laughed at herself. (Deprecatingly or proudly, Meli couldn't tell.) "—But for a man, well, it's nearly impossible without endor-therapy and I know very few men who'll take that over marriage and relief."

Meli understood. "He's trying to set Birch up with Sonia." She said it expressionlessly enough to be proud of herself.

"Unless, of course, he's done for himself. Oh! Now, that came out wrong, didn't it?" She shook her head. "I meant to say, unless Birch has found a local squeeze." She lowered her voice on the last word, glancing at Sonia. "I'd hate her to hear me call her that. After all, she is going to be the mother of my children."

Meli was almost certain the odd tightening in her belly was her uterus contracting. "So you've decided to go ahead and have kids?"

Cari nodded, beaming. "I'm so excited. Sonia's going on the fertility program in about two months. That'll give Clay a chance to find some interim relief. She'll be staying in Nagpur until she delivers. So, congratulate me, already!"

Meli smiled. "Congratulations."

"Now, show me these caves of yours. I've seen holos, but that's hardly the same as the real article. I can't wait to get to work on them myself."

"Sure," Meli said. "Maybe the guys would like to join us."

They did; Sonia didn't. Clay and Birch saw her to her off-dig quarters, then returned to catch up to their wives, who'd gone ahead. It was an off day, the temple paths were empty of diggers and academics, and Clay and Birch met no one on their way up the canyon wall. Cave One was also empty; Meli and Cari were nowhere in sight.

"We'll catch the girls eventually," Clay said, "when they stop to talk shop. Why don't you introduce me to Cave One?"

Birch agreed, turning on the display lights for the inner chamber as they entered.

"Wow!" Clay's eyes swept the spacious cave, flitting from glory to painted glory.

"This one was a residence," Birch told him. "It's thought to have been commissioned by Emperor Harisena himself. The colors were pretty faded when the first teams started work on

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them. As a matter of fact, the first cleaning solvents they used took away as much pigment as they did filth."

Clay nodded. "Organics, yeah. But the restoration is amazing. I'd no idea it had progressed this far. Voluptuous. Absolutely voluptuous. The colors, the styles—" His eyes stopped their journeying on the image of a bronze-skinned, half-naked princess. Her dark eyes gleamed, her elegant fingers beckoned to her equally beauteous male companion. Her breasts, easily the size of melons, were draped with stringed pearls, the luminous white contrasting with the bronzed mounds and their dark, rosette aureoles.

"Beautiful," said Clay. "Reminds me of Sonia. Lucky the man who drew that restoration." He winked at Birch. "Wasn't you, was it?"

Birch scuffed at the floor, realizing how much he'd come to dislike The Wink. "I did, actually. I did her hair."

"Poor boy. All that body work and you end up a hair stylist."

"Yeah."

"Still no relief in sight, huh?"

"What?"

"Of the sexual variety, I mean. You still don't have a squeeze, do you?" It was an accusation.

"Isn't 'squeeze' a sexist term?"

"Sonia thinks it's cute."

Birch looked at the princess—at her hair. "You like Sonia, don't you?"

Clay snorted. "Of course I like Sonia. It's not a prerequisite for our arrangement, but I do like her. Why?"

"Doesn't the idea of sharing her with . . . someone else make you uncomfortable?"

"Why should it? I don't own her, Birch. She's an employee, not a slave. Besides, that would be jealousy, wouldn't it? Jealousy is irrational and destructive. I mean—of course, Sonia's exclusive to me, but that's just a health consideration, not an emotional one. And I'd be more than happy to share her with you." He gave Birch a disconcertingly appraising look. "You're doing for yourself, aren't you? Not that it's anything to be ashamed of, but it's hardly satisfying in the long run and so unnecessary."

Birch's insides were shrugging and quivering like living gelatin. "You know, Clay, this is really none of your business."

"I'm your best friend, Birch. I'm only trying to help."

"Help? By meddling in my most personal life?"

Clay put a hand on his shoulder. "Look, Birch. Every man feels the need to relieve himself. It's perfectly natural. But it's one of those things you have to handle the right way or certain essential relationships start to unravel like last winter's afghan. And when those essential relationships unravel, society isn't too far behind."

Birch cringed. Next, Clay would give a speech about the sins of Victorianism, Free Love and the Oppression of Women—cultural evils solved for a good part of their global society by the trend toward Equilibrium, but still extant in pockets of ignorance. Birch had no desire to hear how his sexual aberrations—real or imagined—were going to invoke their specters.

"Let's find the girls," he said, and left the cave.

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* * *

"This is my favorite cave," Meli said. She waved a hand at the collection of statues illuminated by the soft glow of display lamps. "This is the Hariti-Panchika Shrine. In Hindu lore Hariti was an ogress who—"

"—Ate her children until the Blessed Buddha delivered her from her ignorance," Cari finished. "Lovely story." She moved closer to the group of statues, gazed up into their smooth stone faces. "How serene. How utopic. The Husband/Master, his wife and kiddies. Domestic bliss, huh?" When Meli said nothing she asked, "Meli, why is this your favorite temple?"

"I don't know," Meli lied, then shrugged. Lid was already off the box. "I think it's the Happy Couples. After all, I'm half a Happy Couple myself."

"Huh. With an important difference. You don't have to bear children and you don't have to suffer a relationship crippled by sexual politics." Cari lifted her eyes to the vivid medallion above them. "Ah, I see. More happy couples." She wrinkled her nose. "That's not love, you know, Mel. It looks like love, but it's not. For thousands of years man and womankind have fought tooth and nail, hurting each other in every imaginable way through sexual politics. He demands it; she withholds it. She loves him; he'd rather have good sex. Thousands of years of battle, Mel. Just because we couldn't or wouldn't separate love and sex. We kept trying that impossible combination for centuries because some of us maintained the two were identical, or over-lapping, or compatible, and that we'd someday find a Mystical Balance. Men would be more caring and responsible; women would be more independent, more honest about their desires. You were no slouch in history, Mel, you know all this stuff. And you know the Mystical Balance was a chimera. Love in combination with sex is corrupt and self-destructive; sex in combination with love is manipulative. There is no utopia."

"Isn't that what we have now?" Meli asked the rhetorical question in hope of forestalling further dissertation.

"Well, some of us think so. I think so."

Meli conjured up a false smile. "Then, I guess you're half a Happy Couple, too." She almost added, "Or a third of a Happy Triplet," but didn't. She did something almost as foolish; she asked, "Cari, what would you do if Clay fell in love with Sonia?"

Cari threw back her head and laughed, the sound rolling back in delighted echoes from the stone walls. "Oh, I wish Clay could've heard that! That is the silliest thing I've ever heard! My God, Meli, where were you during Sexual Psych 101? He can't love Sonia, he has sex with her. They've got absolutely nothing in common, except that they can make each other come. Clay loves *me*."

Meli knew she was right. Clay did love her, completely and devotedly. And regardless of what he felt for Sonia (could he feel *nothing* for Sonia?), he could never love her the way he loved Cari. She glanced at one of the Couples, frozen in a touch. "But

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haven't you ever wondered what it would be like if Clay—"

"Wanted me? Judas Priest, Meli!" Cari's face flushed an angry pink. "He wouldn't. Clay loves me. I'm his wife, for God's sake. You don't saddle a loving relationship with that. That's why we hired Sonia. Honestly, Mel, I think you've spent too much time in these ruins. They're beginning to influence your thinking."

Meli smiled. "Nonsense. I just have an archaeologist's curious soul. Besides, I love to hear you hold forth on love, truth, and the American way. Why don't we move on to Cave Three?"

"She said Cave Two was her favorite," Cari mused later, relaxing with Clay before the fire in the parlor of their cottage.

"The one with the Hariti group and the Lovers' Medallion?" Clay shook his head. "Birch said the same thing. Worried me a little."

"You didn't say anything, did you?"

"Unfortunately, yes. He told me to butt out. I gave him the 'I'm-a-caring-friend' speech."

"Is that anything like 'I'm a little teapot'?"

"Be serious. These are our best friends."

"Sorry. I gave a speech too, I'm afraid, on behalf of political correctness and family values." Cari shrugged. "That's archaeologists for you. I guess some of us have a morbid fascination with the dark ages."

Clay smiled, a half-hearted expression that sat, twitching, at the corners of his mouth. "I hope that's all it is."

"Clay?"

The couple looked up in unison from the comfort of the small fireside divan. Sonia stood in the door of Clay's bedroom, her new silk sari wound like a bright cocoon around her perfect body. She'd dyed her hair, bronzed her skin, and applied kohl to her eyes. A long string of faux-pearls dangled from her fingers.

"Bravo!" Cari complimented her. "You look just like Princess Cave One."

"Only one thing missing." Sonia giggled and wagged the pearls at Clay. "I need a little help, Clay. Come unwrap me?"

Cari laughed and Clay wriggled his eyebrows in that ridiculous Groucho Marx way that she adored and said, "Sorry, my sweet, but nature calls."

He slipped gracefully over the back of the couch, his groin already blossoming, and leaned back to give Cari a peck on the forehead.

"Have fun," she said. She almost patted his rump when he turned away, but stopped herself. No sense in sending the wrong signals. Men were peculiarly single-minded in that hormone-flushed state; there was no telling how he might interpret it. She cuddled down comfortably among the tossed pillows and went back to her magazine, thinking only peripherally about the problems between Birch and Meli.

"I wondered where you'd gone." Birch came out of the shadows at the mouth of Cave Two to where Meli stood in the warm glow of the Hariti Shrine. She turned to look at him and

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he was struck once again by how lovely she was. She called herself plain, but he thought she was beautiful. God, but he loved her. He moved to put his arm around her shoulders. "It's late."

"I love this temple," she said. "There's nothing wrong with that, is there?"

"I don't think so. I love it, too. Why do you ask?"

"I mentioned to Cari that this was my favorite because of The Happy Couples, and she all but read me the Equilibrium manifesto."

"Funny, I had a similar experience with Clay."

Meli turned beneath his arm, fixing him with those clear hazel eyes. She thought they were nondescript; he believed they were magic. He felt his groin tighten.

"Birch, do you like Sonia?"

"She's a nice girl, I suppose. A little . . . vague."

"Cari says she's agreed to carry children for them. She's going into fertility in two months."

"Oh?"

Meli's brow furrowed. "I suppose I don't really mean do you like Sonia. I suppose I mean, do you . . . *need* Sonia?"

"Do I need—? No. No, I don't need Sonia. I don't *want* Sonia." I want you, added a blasphemous and fortunately silent voice in his head. "Why do you ask?"

"Cari said Clay brought her along partly for your benefit. Since you . . . don't have anybody. You don't, do you? Have anybody, I mean? A relief . . . person?"

It was cool in the cave; Birch sweated, regardless. "No, Mel. I don't."

"Neither do I." She seemed desperately perplexed. "Birch, you know I love you."

"Yes, of course. And I love you. Desperately," he added.

Meli's full lips compressed. (She said they were fat; he thought they were sensuous.) "When we have children," she said, "I don't want another woman to carry them."

Birch blinked at the bald admission. "That's incredibly sacrificial of you, Meli. I don't know what to say."

"Is that crazy of me?" She pressed against him. "To want to carry my own babies?"

He thought he was going to burst. "I-I don't know. I don't think so. . . . No. No, it's not crazy, at all." Suddenly he wanted to tell her who the princess in Cave One reminded him of. Whose face his mind pasted to that abundant body. He wanted to reveal his Cave Two fantasies about what happy, adoring couples did in their shared (yes, shared) beds. Did he dare?

Before he could decide, Meli said, "And I'll tell you something else. I don't want my children scientifically implanted, either. I want them implanted naturally. . . . But dammit, Birch, I love you."

Before he could respond in kind, their lips touched and they were clinging together like bathers in a swift stream. Before it could register that Meli wasn't resisting him (or was he not resisting her?)—that she was participating—they had dropped

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their respective pants and opened their respective shirts to press flesh to flesh. Birch noted that Meli didn't wear a bra and Meli noted that Birch had furry buttocks. But that was the last thing either of them noted because rational observations have a way of swamping in strong emotion.

With a bedroll of pants and shirts covering the cool, sandy floor, the Asbury-Bocamps coupled with abandon right before the basalt eyes of Queen Hariti and her royal husband and their entire stone brood. The Happy Couples graced them with knowing, painted smiles and the soft lights warmed them, if only slightly. They generated quite enough heat on their own.

It was entirely glorious, if gritty, and was brought to an unceremonious end by noises outside the cave.

"Oh my God," Birch gasped, "someone's coming," and intended no pun.

"They'll catch us!" Meli cut short her own paroxysms and wriggled after her shirt. She couldn't bear the thought of being discovered by Cari or Clay—caught flat on her back in flagrant and aberrant delicti.

They broke speed records scrambling into their clothes—socks wadded into one pocket, underwear into another. In the end, it turned out to be a false alarm; only a delinquent pack mule who would not have cared that a man and his wife were coupling in a Buddhist love shrine. They laughed at the mule, then again at themselves when they realized they had gotten each other's pants by mistake. His ankles were bare, her feet were invisible.

They strolled back to the camp housing arm in arm, feeling at once guilty and giddy and relieved.

"Are we awful?" Meli asked.

"Probably." Birch was silent for a measure of steps. "You really do look like the princess in Cave One. I imagined you did."

"You imagined? You thought about it? About me? Like that?"

"I'm sorry. I know I'm not supposed to, but I want you, Meli. Do you . . . do you feel degraded by that? Because if you do, I can try to behave like—"

"No. No, I don't feel degraded by it. I feel . . . " She grinned, " . . . wicked. But in a very nice way."

Birch sighed, relieved. "I was beginning to wish I was Catholic. I had all these horribly conflicted, unnatural feelings about you and I'd no one to confess them to."

"You must confess them to me, my son," Meli said, and delighted in another wicked tingle. "Every aberrant thought."

They'd reached their cottage and Birch held open the door. "We'll have to be very careful. No one must find out about us. Especially not Clay and Cari. They'd never understand."

"No, never." Meli smiled. "They'd think we were mad." ■

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Pauline Ashwell

TIME'S REVENGE

Any technology can have commercial applications—but some come with special liabilities. . . .

Illustration by Ron Chironna

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On his last three visits my friend the Time Traveler had come to the front door, and I thought I had got him trained. I was all the more startled, therefore, when one evening, as I was microwaving my supper, he arrived through the door of the broom cupboard instead. He had not been *in* the broom cupboard, of course—he is the thinnest person I know, but two brooms, two mops and the vacuum cleaner leave barely room even for another broomstick. The interface between this Universe and the one he inhabits had been set up a millimeter or two in front of the door itself, and he came through that.

It was the first time I had actually seen the process—other times he was just *there,* when I turned around, or looked up, or opened the door. His most prominent features (in the sense of projecting further than the rest)—a tuft of hair, the tips of his nose and his little pointed beard, the knuckles of one hand—suddenly projected from the dark-stained wood, like those of a corpse not quite submerged in melted chocolate. I didn't scream, but I emitted a definite squeak, by which time he had come all the way through and was standing in front of the undamaged door, in a pale grey suit, with a bow tie as usual a little on one side—looking thoroughly upset.

That had nothing to do with my behaviour. I don't think he noticed that I was anything more than a little surprised. He seldom came to visit me except when he was upset. When one of his forays had gone well, presumably he went straight back to his own Universe to report to his fellow workers—they did not, I gathered, go in for superiors over there—and prepared for the next one.

He turned up on my doorstep, or inside the house, every couple of months, but that says nothing about the actual frequency with which things went wrong. He was making use of occasions when my husband would be away. I had given him a list of them. Harold considers himself a realist; if he had been forced to believe in time travel—and even the hardest head gets dented if enough evidence is piled on—it would have seriously damaged his belief in his own sanity, and I was not sure that I knew how to cope with that.

I, on the other hand, believe my own eyes, even when they tell me impossible things. For instance, during a visit to the British Museum, that the gentleman I had seen about ten minutes earlier, in a charcoal-grey lounge suit, asking the warder for directions to the curators' section, had just entered the gallery from the opposite direction wearing a jacket of Harris tweed.

To visit one of the nine curators one has to enquire at Reception and be announced by 'phone, then go to the appropriate gallery, find a bell-push to summon a clerk, and sign the Visitors' Book, before being conducted along a route whose length varies from gallery to gallery, to the curator's room. The gentleman in charcoal grey had spent a couple of minutes looking—I supposed—for the bell-push, before consulting the

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warder on duty, so I had had time to observe him. There was no doubt in my mind that the one in Harris tweed was the same man. He might have gone around through the labyrinth of passages that connects the working parts of the Museum with the exhibition halls; but why had he changed his clothes on the way? Also it seemed to me that his beard was a slightly different shape, his hair a little longer—and hadn't he been sporting sideburns, clipped short but noticeable? His cheeks were now shaved quite clean.

The explanation was obvious. However, one does not come across a pair of really identical twins very often. I took it that they intended to meet and I wanted to see them side by side, so I got behind a large glass case, containing smallish exhibits on glass shelves, and waited for the other twin to emerge. He did so in a few minutes, talking presumably to a curator; they paused at the gate to finish the conversation.

I glanced at the other twin, just in time to see him catch sight of the first and, having registered surprise, shock and horrified understanding in very rapid succession, turn on his heel and hurry back the way he had come.

His double was still talking to the curator, both of them oblivious to Harris Tweed's existence. I came out from behind the case and set off in pursuit.

I had no plan in mind; I just wanted to see what would happen next. I followed him for the length of two galleries and out on to the main stairs; down past the landing with the case of Benin bronzes—no time to admire them—and into the postcard section of the ground floor. He had slowed down a good deal and I was only about six feet behind him when he turned suddenly and looked me in the face.

I didn't have time to expect anything, although I think the words "Madam, are you following me?" sounded momentarily in my mind's ear. He said, "May I offer you a cup of tea?"

The postcard section leads to the Museum's tea shop. It was fairly early in the afternoon and we had no difficulty in finding a table well away from potential listeners. My host went to the counter and returned with a tray containing a fair-sized teapot, milk, sugar and a selection of quite attractive-looking cakes.

He offered me the traditional women's role of pourer-out and I accepted, reflecting that it would also make it more difficult to administer drugs —not that tea is a very promising vehicle for this purpose. Possibly divining this line of thought, my companion accepted the cup I gave him and took a large mouthful, without waiting for me to do so. I followed suit. For museum tea it was not at all bad. The cakes were drier than their appearance suggested, but that was not his fault.

He said, "I would like to explain."

I was amazed at the freedom with which he did so; it was not until afterwards that I realized just how safe he was. Even if I was fool enough to repeat any part of his confidences; even if—still less likely—I managed to in-

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terest anyone in authority—or, of course, the press—they were unlikely to find him. And if by some accident he chanced to have business somewhere and somewhen that they happened to look for him, he could simply disappear—preferably round a corner, but, if necessary, into thin air. This last I did not learn until some time later; but the moment I thought about passing on any part of the story to anyone I realised that I would be simply branding myself as a lunatic, or a practical joker—either of which would cause me to be shunned in future by anyone who heard of it.

As for his motive in telling me, that was simple; he had had a nasty shock and wanted someone to talk to. The boldness of my curiosity had suggested to him that I was unlikely to scream, faint or otherwise embarrass him and possibly that if I did get myself into trouble by talking about him it would simply serve me right.

He had, in fact, been present twice over in the gallery. The reason was silly but, once you accepted the facts of time-travel, also simple; he had double-booked appointments with different members of the Museum staff. The excuse was that on his own time-line the occasions were five years apart, and in recording the first occasion—he showed me a tiny pocket computer with a keyboard that unfolded like a pocket handkerchief almost to standard size—he had made a mistake about the year.

I said I had done the same thing a few weeks previously, when making out a cheque; but couldn't he just have gone ahead and kept the second appointment? If that entailed running into his former self—he would, I suppose, have had to go through the same gate—he could simply have hailed him and explained to the curator(s) that they were twins.

"No, no, *quite* impossible. I could *never* do that."

He sounded as though the suggestion was not only impossible but in the worst of taste, and I was slightly annoyed until he added "Dr. McCollum, with whom I had my appointment, was already approaching; in another moment he would have called to me. Then, inevitably, I must have seen myself—and I *know* that that did not happen."

"But didn't he speak to you—I mean your former self?"

"No . . . I think Dr. Bastable, with whom I had that meeting, was standing between us. I remember, I think, that a man brushed past us when we were standing by the gate and seemed to be looking for somebody. A moment later Dr. Bastable remembered something that he wanted to show me, and we went back to his office, so that Dr. McCollum and I did not meet on that occasion."

"How are you going to explain why you didn't meet on *this* occasion?" I enquired. "If he was coming out to look for you I suppose you must have been announced from the reception desk, so he'll think you got lost somewhere on the way up."

"Yes . . . dear me. I should have returned, with a tale of taking a wrong turning somewhere. It's too late for that now." He pondered. "I think . . . on the stairway I passed a

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lady who was suddenly taken ill, seriously, so that I conveyed her to hospital in a taxi."

"Wouldn't the people on the reception desk have noticed that?"

"Perhaps not. There happened to be a school party coming in . . . they were kept quite busy. And if Dr. McCollum does not believe me he will just think that I was dodging a business rival, or perhaps the police."

"He will?" I said, startled.

"Oh, yes. He thinks, you see, that I deal sometimes in antiques stolen from archaeological sites. Not with him; the jewels I am showing him have a very good provenance, from a collection made in the eighteenth century, but there are times when I can't arrange that." He gave a slightly hunted look at the wall clock. "I think perhaps I should telephone him now and arrange another appointment."

Having watched a good many archaeological programmes on television, I knew that people who stole from sites were dreadfully wicked, and for a moment I missed the significance of his last remark. I grabbed his coat sleeve just as he was going away.

"Look, there's a lot more I want to know. Can't we meet again?" He probably would not want to come to the British Museum again for a bit and there are not many tea shops in London now. I fumbled in my bag and found an envelope with my address, I don't carry visiting cards, and scribbled my phone number beside it. "Look, any time you're in Wimbledon, why don't you just drop in?"

He looked pleased as well as surprised, but I never really expected anything to come of it. However he turned up that very evening—at the front door that time—carrying a bottle of whisky from which he accepted one drink. (Harold and I don't care for spirits, and know little about them; but on a later occasion, when we had to entertain his managing director, the remains of the bottle caused quite a stir, and I had to invent a mythical deceased uncle from whom I'd inherited it.) He came, I think, partly for the kind of reason that makes people visiting foreign countries feel one-up when they manage to rub shoulders with a "local"; but mostly because he was lonely. Later we became friends, but right then he wanted somebody to talk to, and having deliberately involved myself in his affairs I was fair game.

Anyway, he wanted me to understand that he did *not* steal from archaeological sites or anywhere else; the items he sold had been bought from the artists who made them, at the going rate. The problem was that these transactions were not accompanied by the usual records, since they had taken place about 2,500 years ago.

"But then scientific tests would show that they were quite new," I said, airing the expertise I got from various TV programmes.

"Oh, we don't put them on the market straight away, of course. We bury them in the right kind of soil and dig them up a couple of thousand years later."

I blinked. "Is that safe? Suppose someone else found the spot?"

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"They were buried in—I forget just when—some time in the Pliocene, I think. In any case, well before the appearance of *Homo sapiens.*"

I blinked again.

"So," continued the Time Traveler gloomily, "everything I handle has an authentic patina, authentic attribution—I insist on having the pieces signed—and passes all scientific tests; and half the time I *still* have to pose as a grave-robber in order to sell it."

"How about the other half?" I enquired, fascinated.

"For the other half I manage to blame the grave-robbing on somebody else. Usually some anonymous person in the eighteenth century, before the laws against exporting national relics came into force. There were quite a number of collectors then, and some of their collections got dispersed, without any record of where the items ended up. So with certain types of objects one can . . . er . . . lay a trail suggesting that they were bought from the original finder by Lord So-and-so or Prince Whatsisname, and later passed through various hands, until they ended up in mine. Especially, of course, if they correspond to some item included in the catalogue of that collection, which has since disappeared. For example—am I boring you?"

I assured him, with the utmost sincerity, that he wasn't.

"Well then, for example, take the last thing I commissioned—only a couple of days ago in my lifetime. The catalogue of the seventh Duke of Pontecalmo's collection lists a life-size bronze statue of Persephone, attributed to Theodoros. You've heard of him?"

"The Samian sculptor?" I said.

"That's the one." He was not particularly impressed by my knowledge: I decided not to mention that it derived from a novel by Mary Renault. "So I went to Samos in—" he paused, evidently calculating. "By the present calendar it would have been 528 B.C.—"

"You went there yourself?" I exclaimed. I don't know quite how I had thought the transaction was to be arranged; probably I had been too absorbed in what he was actually saying, to extrapolate from it. I wonder how he would look in a tunic and sandals; of course a lot would depend on his legs. Or did men in their fifties stick to ankle-length robes?

"Of course. That's where most of the fun lies . . . I speak Greek of that period, of course, with a moderate Persian accent; and Persian with a Corinthian accent. One can't simply pose as a Greek, you see; it would have to be a citizen of one particular *polis,* Athens or Thebes or Sparta or whatever. Then you'd almost certainly run into fellow citizens and be asked about your relations and which of the twelve tribes you belonged to, and if you told him that he'd want to go into the matter further; it's much safer to be a foreigner. There are plenty of them around in the big cities. For Theodoros's benefit I was the agent of a Persian nobleman—a minor one he wouldn't expect to have heard of, but with an eclectic taste in bronzes."

"But aren't Persians pretty unpopu-

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lar in Greece?" I enquired.

"Not at that time-point. Marathon won't happen for nearly forty years. They're a bit wary of Cambyses, but they admired his father, Cyrus. No, I ought to have been safe enough."

"*Ought* to have been?" I said.

"Oh—well, as it turned out I didn't come to any harm, but I mistimed my visit a little. I stayed on Samos to see the work start on 'Persephone.' After I'd been there a week I went down to Theodoros's yard, in the afternoon, because he was going to finish the core of the statue from the model and I was curious to see her. The core of a big bronze is made of clay, you know, and modeled just like the statue except for the fine detail. He'd been building up the bulk of it for a couple of days, allowing each layer to dry, partly, before he attached the next. A layer of fresh clay had just been applied all over, ready for the finer modeling, when a tremendous row broke out nearby. The yard was in the lower part of the town, quite close to the docks. What had happened—do you know anything of samian history?"

"Not very much," I said cautiously.

"Well, around that time the ruler, Polykrates, had tried to get rid of some . . . er . . . dissidents, by shipping them off to visit Cambyses—ostensibly as a sort of embassy, but actually carrying a letter which asked Camybses to have them all put to death. However, they were cannier than he expected; opened the letter on the way and turned back, intending to take Samos over. They didn't succeed; Polykrats and his mercenary troops were too much for them; but for some hours there was a running battle going on in the lower town and that was what we'd heard. It's all on record, of course, but nobody gives the dates; and historians' best guess was that it had all happened the year before.

"Theodoros had been working on the statue out of doors, so that the clay would dry sooner. When the row started his first idea was to get it into the workshop. It was standing on a large board, which was moved about on rollers; but it was an awkward thing to shift—the ground wasn't exactly level and every time it hit a bump somebody had to steady the figure in case it toppled—I did it a couple of times myself. However we got it inside, and Theodoros barred the doors—with all of us still in there; it didn't seem a good idea to be left outside. Theodoros just settled down to make sketches of the model from various angles, and the assistants started a dice game in one corner, and I . . . just wandered around. In a couple of hours the noise stopped, and after another half an hour somebody went out and found all quiet, and by then it was getting on for sunset, so we all went home.

"No trouble, in fact, so far as I was concerned, except that I'd been carrying my E.T.T. in my hand, as a precaution, and—"

"Your what?" I interrupted.

"My—oh. E.T.T.—for Emergency Trans-Temporator. It's a safety device. If things go seriously wrong and we can't get to an interface—" He

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stopped, pulled at his beard, and started again.

"Did I explain that my . . . er . . . base of operations is in another universe? Not one of these parallel affairs people write about. It's a kind of offshoot of this one, but independent—with its own dimensions of space and time. We can set up an interface between it and this one at any place-time we choose, and go through; but that can only be done from the other side—my home side, I mean. We don't have the . . . er . . . machinery in this Universe.

"The usual practice is to set up two or three interfaces, beside recognisable landmarks, so that if for some reason one of them can't be reached we have an alternative. The E.T.T. is only for use in really urgent danger. It's always carried, when one of us is in the Main Continuum. It's quite small, about an inch long and weighing a couple of ounces—but not primed unless there's likely to be serious trouble. Once it's been primed a simple twist of the activator will take you straight back to base. You disappear, in fact, with a loud pop—that's the air rushing in to fill the space."

"Startling for bystanders," I said.

"Exactly. That's one reason why we don't use the thing if we can possibly help it. The other is that being shot from one universe to another is unpleasant and rather dangerous. One or two people have arrived dead—asphyxiated. We're warned to take a deep breath before using the thing and to hyperventilate if we have time, but in an emergency people sometimes forget."

I found that I had taken a deep breath myself and was holding on to it. I let it go, feeling foolish, and said, "Did you say you'd *lost* the thing?"

"Absolutely. I remembered taking it out and priming it, soon after the noise started, and then holding it in my fist . . . and then I suppose I forgot about it and let it drop. . . . Oh, don't worry. Theodoros won't suddenly find himself in another universe, even if he were to pick it up and fiddle with it. It won't work for anybody else. It's sensitized to the chemistry of my skin."

"Yes, but what happens if you get into *real* danger and haven't got it?"

"Oh, I picked up another one. It was a nuisance—I had to spend two days at . . . er . . . base, waiting for it to be ready. Then I decided to attend to various matters in this placetime before returning to Samos. I'd spent nearly nine months in various parts of the sixth century B.C. and I felt like a change. . . ."

The Time Traveler left soon afterwards and I sat in my nice conventional suburban sitting room, contemplating the armchair from which he had just risen and wondering whether the whole episode had been a dream. . . .

A week or so later, however, he dropped in again. Fortunately, although Harold had returned from his latest business trip, he was not at home at the time. It was then that I gave the Time Traveler a schedule of occasions when he could conveniently call on me; and he used it faithfully from that day on.

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The arrangement had been in force for about a year and a half, so far as I was concerned. I gathered that in his lifetime the interval had been three or four times as long. He never looked any older to me; but on this occâsion he looked tired, discouraged and down in the mouth. He flopped into his usual chair and sat there, staring at the carpet. I gave him a glass of his own whisky (the original bottle had been replaced several times) and asked what had gone wrong.

He uttered a sort of groan, pulled an envelope from his pocket, sorted through the photographs inside it and handed one across.

"Look at that," he said.

In showed the figure of a woman, in polished bronze. She sat on a kind of throne, looking straight ahead —straight out of the picture. It was a most striking face; young, but formidable. The inlaid eyes with their brilliant white and dark irises were intimidatingly alive.

I remembered his first visit to me.

"This is your 'Persephone,' isn't it?" I said.

He gave a miserable nod and sank his head in his hands.

I looked at the picture again. Persephone, Queen of the Underworld. Yes, she looked like that. Now that I knew for sure, I could see other things in the face besides its power; traces of the young girl, Demeter's daughter, picking flowers in the meadow from which Hades had snatched her into his dark chariot; memories of spring and summer in the world of the living, won for her by a mother who was also formidable in her way.

"Who was the model?" I asked.

"Oh, she was a hetaera. No marriageable girl would pose, and of course no married woman. Theodoros told me something of her history; she'd been stolen by bandits when she was twelve years old, and carried off to their stronghold in the mountains. About three years later the bandits became such a problem that the local lords got together to hunt them down. The men were killed fighting and the women sold as slaves. She was bought by a hetaera who took a fancy to her, had her taught to read and sing and play the lyre and the rest of their arts. The mistress died after a couple of years, killed by a jealous lover; the girl was enfranchised under her will. She became a hetaera herself, and worked her way up from the provinces to Samos. She wasn't at the top of her profession—too outspoken and not flexible enough in accommodating herself to clients' fantasies, but she was building up quite a reputation all the same."

He had revived somewhat while he was speaking, but heaved a sigh and relapsed into gloom immediately when he stopped. I looked at the photograph and tried to assimilate what he had told me about the original. A story that seemed straight out of a classical bodice-ripper; and yet, looking at that face, entirely believable. Of course, Persephone also must have been a survivor, in her own way . . . .

I roused myself to say, "So what went wrong?"

The Time Traveler took his head

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out of his hands and looked puzzled.

"I asked why you look as though you've been through the shredder," I said, inaccurately, "and you handed me this photograph. The statue looks perfectly OK to me. Did it get damaged, or—" I realised suddenly that it did not look in the least as though it had been buried for 2,500 years—"did you forget, and polish the patina off it, or what?"

"No, no." It came out like another groan. He fumbled out another photograph and gave it to me. It showed the same figure, but with the smooth dark greenness that comes from long aging of bronze without interference. The throne was gone; Persephone sat on a boxy wooden chair, instead. If anything, she looked even more impressive than before.

"Well, then," I said, puzzled, "what went wrong?"

He buried his face in his hands again; but after a few seconds he straightened up and tried, rather resentfully, to make sense.

"We took her off the throne because we buried her—it was a lot easier that way. She'd been fastened to it with rivets. When we dug her up the area around the rivet holes was somewhat corroded, in places the bronze actually flaked away. I invited my contact at the British Museum to come and see her—"

"Where?" I interrupted.

"Oh, I hired a bank vault to keep her in. I had to bring in a couple of spotlights for his inspection, of course. He was absolutely overcome when he saw her; spent a long time just sitting and staring. Then he asked if he could take samples from the damaged area, for scientific tests. Of course, I agreed."

"Of course," I said.

"The asking price was two and a half million-pounds, I mean. Of course, he had to discuss it with his colleagues, but he thought he knew a handful of millionaires who could be persuaded to put up the cash. He was supposed to get in touch with me three days ago."

"Didn't he?" I asked, after the pause seemed to have gone on long enough.

"No. I was puzzled. I tried to call him, but was told he'd gone out of the country. That seemed most unlikely; he would surely have let me know. In the end I broke into the Museum's computer, to find out what had gone wrong."

I was momentarily startled; then I remembered that breaking into a computer did not involve physical violence.

"Did you find out?" I said, when it seemed that nothing more would be forthcoming without a prod.

"Oh, yes. I found out." He made a very small gesture that somehow conveyed infinite despair.

"Well, was something wrong with the—the thermoluminescence or something?" This method of dating baked clay objects, including the core of bronze statues, had featured largely in a couple of archaeological paperbacks I had read recently.

"No, not that. The estimated age was 2,350 years plus or minus 400—quite close enough. It was the bronze that was wrong."

"What?"

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"The proportions of copper and tin were within the usual limits for the period, but there was more than half a percent of other metals. Under X-ray fluorescence it showed traces of half a dozen metals—lithium, iridium, niobium, cobalt, samarium, nickel. They were all concentrated in one part of the flake. There was not enough of it for quantitative analysis, but the analysts guessed that the proportion of metal other than bronze in one spot was something like three percent. So he analysed the clay of the core and found traces of several of the metals in that, as well."

I mulled this over and could make nothing of it.

"How bad is that? Couldn't Theodoros just have got hold of some ore that happened to have these other metals in it as well as copper?"

"Cobalt, perhaps, and nickel. Not the rest. The only way you'd find that assemblage of elements together would be if they'd been *put* together, in an artifact of some sort. And nobody even knew that most of them existed, until the nineteenth century A.D."

"Then how did they get into the bronze?" I said.

The Time Traveler wiped sweat from his brow with a hand that shook, noticeably.

"The only explanation that the analyst could suggest was that somebody had dropped an artifact containing them into the clay, while it was soft. And the only way that could happen was if the statue was a fake. A very *recent* fake. Samarium, for instance, was not used for anything whatever until the last half of the twentieth century, when it was incorporated in magnets." He gave a heartrending sigh. "My contact was terribly disappointed, poor chap. And everybody at the museum is terribly worried, because if the statue is a fake it means that thermoluminescence measurements can't be trusted any longer—I would have to have faked those, too."

"Yes, but how—" I halted, struck by a memory. "The first time you came here—that thing you'd lost—with the initials—"

"The E.T.T.?"

"Yes. What was it made of?"

He heaved a sigh all the way up from his boots.

"You're quite right, of course. It contains all those elements. When the statue was moved into the workshop the clay was still soft. Once, I remember, the whole thing tilted—the figure toppled forward. I was behind it, I put out my hand to hold the seat level—"

"The hand with the E.T.T. in it?" I said.

"I suppose so . . . If I had let go of it it would have rolled down—and then—"

The words that trembled on my lips were "She would have sat on it?" I suppressed them. Instead I said, "So what happens now?"

Visibly, he pulled himself together.

"First—tomorrow—as soon as the bank opens I go to the vault and scrape out more of the core, until I find the remains of the E.T.T. Then . . . " He relapsed into apathetic gloom.

I prodded gently. "What will the

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museum people do, I wonder?"

"Oh, lord . . . Dither around checking things for as long as they can. Then once they're absolutely certain of their ground they'll notify me they're not interested, and warn every other major museum that I've started selling fakes as well as stolen goods. I'll be finished, so far as they're concerned."

"And what about the statue?" I said.

"Oh, I'll take that across to America and take it around to a few of the big collectors. They don't have access to the museum grapevine; they'll do their own tests and be happy. I'll make damned sure I've removed all the affected sections."

"I suppose it means you won't get your full price, though," I said.

"No, why? I'll probably get more than I would have done from the B.M., especially if I get an auction going between rival collectors. The museums are hard bargainers; they expect you to take part of the price in prestige. . . . But, damn it, I hate to sell Persephone to someone who'll keep her to himself, except when he wants to make somebody jealous."

"What will you *do* with all the money?" I asked. It had suddenly occurred to me to wonder about the value of a bank balance to somebody domiciled in another universe.

"Oh, it will be used. . . . We buy a great many things here—in this place-time, and others. Machines, instruments, all kinds of equipment. There aren't enough of us to make all that we need, even if we wanted to spend our time that way—"

"What's the equipment for?" I persisted.

"Oh, we have a good many projects," said the Time Traveler vaguely. He caught my look, and was suddenly amused, for the first time that evening. "Don't worry; they do *not* include taking over the Earth, now or at any future time. . . . We do make use of certain placetimes in the past, though. There's one island in the Late Jurassic . . . I think I might spend the rest of my life there, watching the sea. . . ."

"The rest of your life?" I exclaimed.

"It's time I retired. This proves it. A blunder like that . . . I may have set a permanent question-mark against the reliability of thermoluminescence. It's reasonable to make use of the facilities in this Universe and pay for them at the going rate; but one mustn't upset people unnecessarily. No, I shall retire to the Fortunate Isles and study the ammonites in the rock pools; I can't do any harm with that."

I swallowed hard and tried to keep from showing my dismay. I had not realised how important the Time Traveler's visits had become in my pleasant, prosperous, humdrum existence. I felt as though the most fascinating book in the world was being snatched away from me, half read; but it was worse than that. I knew that in time I would begin to wonder whether our meetings had ever really occurred, or whether I had allowed some middle-aged fantasy to take such possession of my mind that I ended up by believing in it; and I hated the thought of it.

The Time Traveler's glance fell on his half-finished whisky. He took up the glass and swallowed the rest.

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We sat for a minute or two in silence. I, at least, had no idea what to say. The Time Traveler pulled absently at his beard.

"You know," he said thoughtfully, "it might be worth while to try one of the big American Museums. They tend to be quite sceptical about test results that they haven't checked for themselves. And since I'll have removed the source of the anomaly. . . . Yes, I think it's worth a go." He put down the glass and rose to his feet. "Do you mind if I go through your kitchen again? I'll site the interface more carefully next time. . . . "

Dumb with relief, I followed him into the kitchen. He raised his left hand and pressed the bezel of his signet ring against the door of the broom cupboard. It made no difference that I could see, but—

"See you in a couple of months," said the Time Traveler. He merged himself with the woodwork, and disappeared. ■

Life is a tragedy for those who feel, and a comedy for those who think.

—Jean de la Bruyere

It is a profitable thing, if one is wise, to seem foolish.

— Aeschylus

What we anticipate seldom occurs; what we least expect generally happens.

—Benjamin Disraeli

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CERN IN TRANSITION

I'm writing this column from CERN, the center of European high energy physics. I and my co-workers have come here for two months to work on a new ultra-relativistic heavy ion physics experiment, NA49, which uses the new CERN beam of lead-208 nuclei that have been accelerated to energies of 160 GeV/nucleon, a total energy of 33.3 TeV (3.33×10^{13} electron volts) for each lead nucleus. Now, (Nov. '94) with a week of beam time remaining, we are working very hard and the experiment is beginning to collect good data. In this column, I want to describe the situation here at CERN.

CERN spreads out over the rural countryside near Geneva, Switzerland, a lake town located in a broad valley surrounded by the Swiss and French Alps. Geneva is strategically positioned at the point where Lake Leman flows into the Rhone River. The CERN campus is on the west side of Geneva near the village of Meyrin. The laboratory demonstrates its international character by sprawling across the border between Switzerland and France. CERN's two largest accelerators, the SPS and LEP, are both built in ring tunnels that burrow under both countries, so that their particle beams cross two international borders with each transit of the rings.

The CERN laboratory is supported by 14 European member states that provide financial contributions based on a complex formula involving the population and gross national product of each country. This year, with Europe still struggling to recover from the worldwide recession of the early '90s, CERN is in a period of turmoil.

The laboratory has for a decade been making plans to build what will be the world's largest and highest energy particle accelerator, the Large Hadron Collider (LHC). (See my AV column in the May '92 *Analog*.) The LHC will use superconducting bending magnets with very high magnetic fields (about 10 Tesla) to bend two oppositely-directed proton beams into twin circular paths with diameters of 8.6 km. The two beams of protons will be brought into head-on collision, with a total collision energy per particle pair of about 15.4 TeV (1.54×10^{13} electron volts), 8,200 times the mass-energy of two protons at rest.

The high energy physics community is very enthusiastic about the prospects for new physics with the LHC, which may hold the key to discovering

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the Higgs boson and understanding the "splitting" of the strong and electro-weak forces into two separate and very different fundamental forces. Two large proton experiments and one heavy ion experiment are now being planned for the new accelerator.

Interesting physics notwithstanding, many CERN member states that are to provide the funding for the new facility are presently having severe internal budget problems and are showing increasing reluctance to contribute their allotted share to the LHC project. In particular, Germany, which has traditionally contributed generously to the CERN budget, is staggering under the enormous cost of reunification and has asked for a long stretch-out of the CERN schedule for LHC construction. The CERN technical staff is circulating petitions and holding meetings to protest this probable stretch-out and the severe reduction of accelerator scientists and technicians that it would bring.

From the perspective of the particle physics community in the USA, however, the situation at CERN looks very good despite the LHC funding problems. American physicists are still reeling from the shock of the cancellation of the Superconducting Super Collider (SSC) project, which would have been the centerpiece of experimental particle physics for the next two decades and would have produced proton-proton collisions 2.6 times more energetic than those of the LHC. In early 1994, with its great ring-tunnels carved half way around the needed circle in the Austin chalk deep under Waxahachie, Texas, and its first superconducting magnets just being tested, the SSC project was killed in its cradle by a flinty-eyed budget-cutting US Congress. From the Congressional debate that preceded this decision there was little understanding, from either SSC proponents or opponents, of the project or its goals.

In the wake of the recent 1994 Congressional elections, there have been tales here at CERN of a "Curse of the SSC" effect. The rumor is that there is a remarkable correlation between the House Members who voted against the SSC and those who were defeated for reelection this November. Even if this rumor is true, however, the turnover in Congress comes too late for the SSC, a dead project with no chance of being revived.

The SSC cancellation leaves US particle physics with years of wasted effort and facing a dead-end. The next generation of particle physics experiments at the highest energies will be conducted in the coming decades in Europe by experimental physics groups dominated by Europeans. American particle physicists have little choice but to join the CERN experiments on whatever terms they can arrange.

These terms are now being negotiated. Earlier this week Dr. Martha Krebs, Director of Physics Research of the US Department of Energy, made a short visit to CERN. I had met her in the 1970s, when she was a scientific staff member for the House Science and Technology Committee, and knew her to be sharp and sensible. She is now a top scientist administrator at the DOE and oversees a $3 billion bud-

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get. She had come to CERN to look over the laboratory and to take the initial steps in studying possible US participation in the LHC project.

Physicists at CERN are optimistic that a deal will be arranged. CERN needs extra funds for the project and the USA needs an alternative to the SSC. In the coming year an elaborately choreographed dance will take place between CERN management, DOE officials, and Congressional representatives on the details of the arrangements.

As a part of her visit, Krebs spent an hour with the American physicists at CERN. There were about 80 of us in the CERN Council Hall, many from my own experiment since this is the month for heavy ion running at CERN and many of the Americans from the proton and electron experiments have already gone home. In broad strokes Krebs described the physics program of the Department of Energy and our place in it. She clearly delineated the rivalry and inter-dependence of fundamental science and applications. She also touched on the difficulty of communicating the value of scientific research to administration officials and Congressional staff, many of whom have law degrees.

After her talk, Martha Krebs asked for input from us. She wanted to know what it is like for Americans to do physics at CERN, to have to come here for months or years to do our work. She was concerned that US participation at CERN might produce a "reverse brain drain." She wanted to understand what kind of training the American graduate students at CERN receive.

When she opened the floor for questions, there were many, most of them centering around the SSC cancellation and its implications. The international speech patterns of the questioners was interesting. While all were from American institutions, few had accents that would have branded them as Americans. The formal question period ended with a coffee break, and a circle of us continued the discussion with Krebs. She was optimistic about the prospects for basic science in the new US Congress. She was interested to hear that while staff positions at US high energy laboratories were open to all, those at CERN were reserved for citizens of member states, with US citizens largely excluded.

I left the meeting with some optimism. In the present situation, CERN needs US participation in the LHC, and the US particle physics community needs large-scale participation at CERN. It is a marriage made in heaven. Martha Krebs seems an ideal matchmaker.

Our NA49 experiment is located in the North Area of CERN, a complex of offices, workshops, and experiment halls in Prevessin, France, about 2 kilometers from the main CERN complex in Meyrin, Switzerland.

About a decade ago, the CERN leaders decided to devote some of their resources to a new kind of physics, the physics of ultra-relativistic heavy ions. Instead of accelerating electrons or protons (hydrogen nuclei), they concluded that it was feasible to use the CERN synchroton complex to accelerate the nuclei of heavier atoms to near

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light-speed. The collision of such a nucleus with another nucleus at rest was expected to produce a nucleus-size fireball of extremely high energy density, a mini-Big-Bang in the laboratory. In theory, if the energy density in the fireball is high enough, we might produce a quark-gluon plasma in which quarks and gluons become free particles in a continuous plasma-like state that may have existed in the first microsecond of the Big Bang.

The initial CERN heavy ion program, beginning about 1986, used the SPS to accelerate nuclei of ^{16}O (oxygen-16) to 200 GeV per nucleon. Since that time, CERN has devoted about 1 month per year of its running schedule to producing heavy ion beams. In 1990, beams of ^{32}S (sulfur-32) at 200 GeV per nucleon became available. Now, in late 1994, CERN is beginning to accelerate ^{208}Pb (lead-208) to 160 GeV per nucleon. Lead ions in a very high charge state are produced in an electron cyclotron-resonance ion source built in Grenoble, France, accelerated by a new linear accelerator built at the GSI Laboratory in Darmstadt, Germany, further accelerated in the recently refurbished CERN Booster Synchrotron, then accelerated to about 1 GeV per nucleon in the Proton Synchroton (PS), and finally accelerated to 160 GeV per nucleon in the Super Proton Synchroton (SPS). In early November the first GeV per nucleon lead beams from the SPS were delivered to our experimental area, and we started to make measurements and collect data.

The collisions make a few thousand particles, which are tracked in our large time projection chambers (TPCs). The TPCs use about 80,000 channels of electronics, each channel with its own amplifier, charge storage array, and analog-to-digital converter. We have been collecting data for about a week, gulping down data at the rate of 6 megabytes per collision event, with several thousand events per day. We have already produced some spectacular pictures from the TPCs, starbursts of pions streaming from the collision like a surreal Star of Bethlehem.

The physics understanding of the mini-Big-Bang we are producing will require some time for analysis and calculation. However, we already know that with the lead beam we are producing about 6 times more particles per collision than in previous experiments with sulfur beams, and that we have reached a new high in energy density, about 3.5 GeV per cubic femtometer as compared to the old "record" of 2.5.

Theory suggests that this density should be enough for quark-gluon plasma formation. Is a clear signature of a quark-liberating plasma or some other "new physics" buried somewhere in the terabytes of data we will collect? We don't know yet. But we are carefully looking where no one has looked before. We stand a good chance, we think, of seeing what no one has seen before. ■

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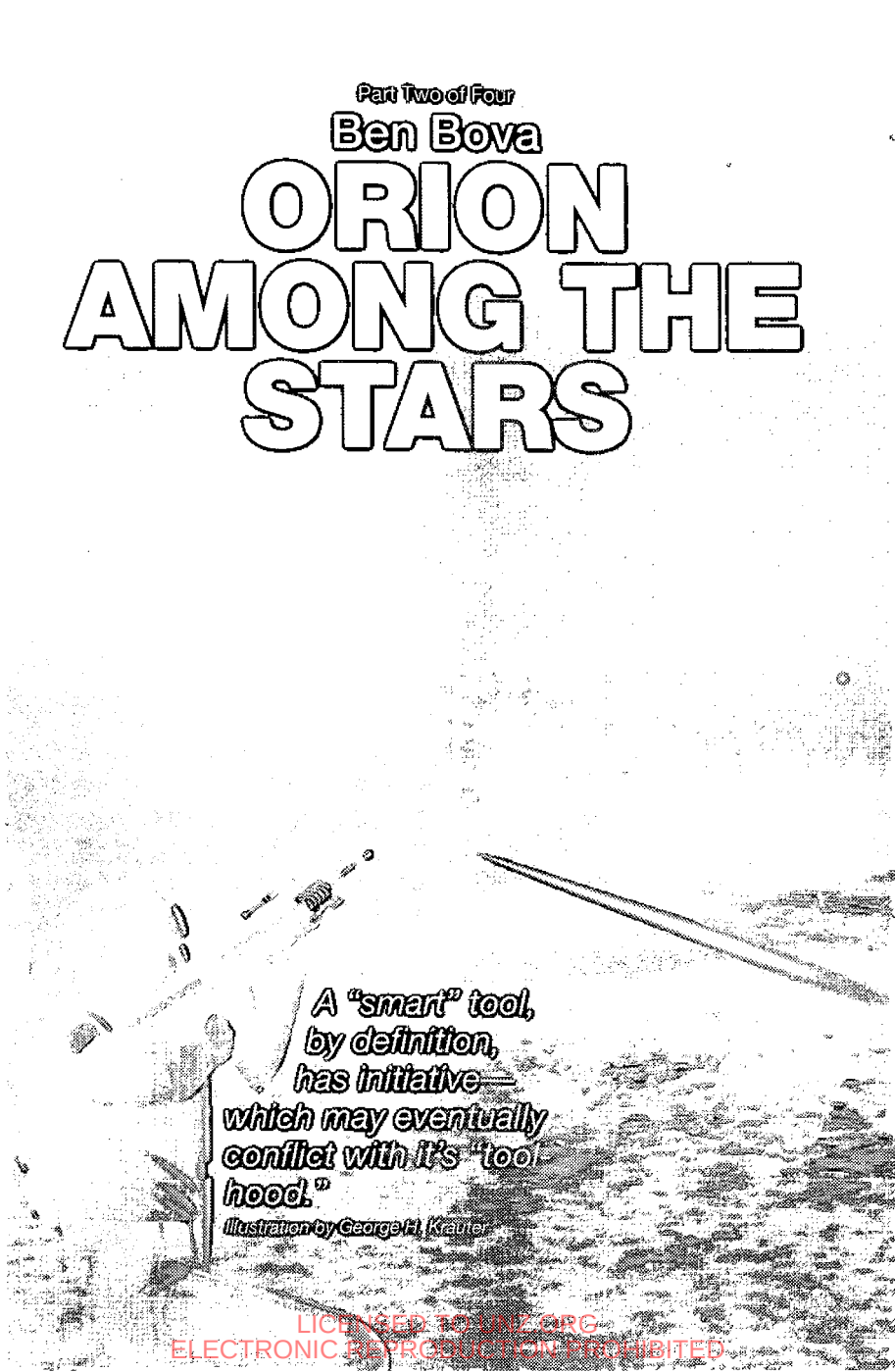
Part Two of Four

Ben Bova

ORION AMONG THE STARS



A "smart" tool, by definition, has initiative— which may eventually conflict with it's "tool" hood."

Illustration by George H. Krautter

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SYNOPSIS

I am Orion.

I was created by Aten, the Golden One, and sent through time to do his bidding. I have fought at Troy and Jericho, I have done battle when dinosaurs ruled the Earth. I have died many times, to be revived by Aten and sent on other missions in spacetime.

Aten claims he created the human race; that he sent me and others of my kind back in time to destroy the Neanderthals and prepare the Earth for Homo sapiens, *his creatures. If he speaks the truth, then we are his ancestors. His, and the other Creators as well.*

There are many Creators. Often in ancient times they allowed themselves to be worshipped as gods and goddesses. I loathe Aten and the other Creators, even though I am bound to do as they command.

But there is one Creator whom I love: the beautiful Anya, who has helped me and protected me over the eons and light-years of spacetime. And she loves me; a goddess and a creature, in love.

Now I find myself in the midst of a vast interstellar war, in which humans are allied with a reptilian race called the Tsihn. I am captain of a combat team that has been sent on an impossible mission.

The soldiers are literally born in the army. Both men and women, they are clones who have been raised strictly for military duty. They have never known any other life but warfare. Between battles they are frozen cryonically; it's cheaper than feeding them.

My combat team has been sent to the jungle planet Lunga, which is held by troops of the Skorpis, a race of giant catlike warriors. The mission has been a disaster from its outset. Hugely outnumbered, my team was nearly wiped out by Skorpis attacks and abandoned by the Tsihn battle fleet in orbit about the planet.

I led the survivors halfway across the planet to the main Skorpis base, on the shore of a tropical sea, intending somehow to attack the enemy. Lt. Frede, the woman who is my second-in-command and bunkmate, is having treasonous thoughts of abandoning the fight and living off the land, forgetting about the war and merely trying to survive in the jungles of Lunga.

My orders are to fight the enemy. I am Orion, the hunter, the warrior. I will fight to the death.

But first I must scout out the Skorpis base. I have decided to approach the base from the sea. Alone.

PART II.

CHAPTER 8

The water was surprisingly warm.

I had expected the bay to be cold, fed as it was by the river that came down from the snowcapped mountains. But instead the water was almost bath temperature, warmed by the Sun during the long hot days.

The current was strong and swift, once I got away from the shore. I made a mental note to remember that for when I returned. I would have to struggle against the current unless I hugged the shoreline closely. The

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flightpack would help, of course, if it wasn't drained of power or corroded by the salt water.

With a final wave to Frede and Manfred, who had accompanied me to the edge of the bay, I ducked beneath the surface and let the powerful current carry me out to sea. I had stripped down to nothing more than shorts. The only equipment I carried was my pistol, my knife, and the flightpack strapped to my back.

I have strengths and abilities far beyond those of normal humans, even the cloned warriors that made up the involuntary army of this era. I could stay underwater for a quarter of an hour without difficulty, and even longer if I needed to; in an emergency I could squeeze spare oxygen from my body cells.

But I am not superhuman. I knew that if one of those tentacled swamp things got its grip on me now, underwater, I would be face-to-face with death. My laser pistol would work underwater, but only at very short ranges. The water absorbed laser energy very quickly.

I wished that we had oxygen tanks with us, so that I could remain underwater indefinitely. But we did not. Oxygen tanks were not among the equipment we had carried to the planet with us. I wished that the flightpack could push me through the water faster, but I dared not drain its power pack too quickly. So I had to be content with allowing the current to carry me along, saving the flightpack for when my muscle power alone would not be enough to propel me where I wanted to go.

When I broke to the surface I saw that I was already past the curve of the shoreline. The sun was high overhead, the swells of the ocean driving up onto the long white beach where the waves broke and boomed relentlessly. I swam out beyond the surf, using the flightpack to help me against the tide, and then struck out parallel to the beach, heading for the Skorpis base.

The salt water was beautifully clear and lit by the afternoon sun. I could see brightly colored fish by the hundreds sparkling and dashing about. A sleek deadly-looking hunter slid through the water farther out; it paid no attention to me and I did nothing to change its attitude. None of those tentacled things from the swamps, thank fortune. I had no desire to get tangled with one of those again.

When I came up for a gulp of air, I saw that I had made precious little progress toward the Skorpis base. Must be a current running against me, I thought. Or perhaps the tide is moving slantwise with respect to the beach. Reluctantly I notched my flightpack to a slightly higher power and dived beneath the waves again.

In the distance, through the crystal water, I saw what at first I thought was a reef. Fish swarmed all around it, a glittering moving rainbow of coruscating colors and flashing movement. As I came closer, though, I realized that it was not a natural formation but a set of structures built underwater and crusted over with coral and seaweed and a thousand other forms of shellfish and underwater plants.

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I popped to the surface again to get my bearings. The ruins of the ancient city lay up above the beach. These underwater structures were part of that city, I guessed. Probably there were tunnels connecting the two. I tucked that possibility into my memory; it might be useful later.

I swam to the coral-encrusted structures. There were long arms reaching from the shore out to sea a kilometer or more, buttressed by stout pillars and cross-bracing. Whoever had built the city had built these structures, too. But why? I could discern no reason for them, no hint of their purpose.

Predators lurked there. As I glided along the structures, looking for something that might be an entrance, I saw a flicker of movement. A brightly-colored fish suddenly disappeared in an eyeblink-fast snap of jaws. Looking closer, I saw a long eel-like thing hovering by one of the girders, its head filled with glinting teeth and a pair of beady eyes. Stretched along the girder it was almost invisible until it moved. I reached for the combat knife strapped to my thigh. Its presence gave me some comfort.

I spent some time examining the ancient structures. If there were any hatches or airlocks in them they had long since been cemented over by coral and barnacles and other sea life. It was bitterly ironic. The intelligent beings who had built this underwater complex had long since vanished, probably self-destructed in a genocidal war. Now their magnificent structures served as homes for fish and crustaceans and seaweed and the lowliest forms of life on the planet.

Then I saw something big prowling through the water. Something with arms and legs.

Like the snapping eel, I froze in place beside a crusted buttress, hanging in the water with my feet dangling, holding my breath. By being still I could be almost invisible. Or so I hoped.

Three of them. Three human shapes gliding through the water a few dozen meters away. Skorpis? It was difficult to judge distance and size underwater. Two of the shapes were considerably larger than the third. They seemed to be escorting it as the three of them swam along. They wore bubble helmets and had flippers attached to their feet. As they came nearer I saw that each of them was encased in skintight suits that bristled with equipment. Yet I saw no weapons on them. I could not make out their faces, but they seemed big enough to be Skorpis warriors. At least the two of them did. The third? A child?

I scanned my memory for information about the Skorpis. Yes, they traveled as tribes. Their society was matrilineal; their leaders all females. Warriors could be male or female, both were of the same size, there was no sexual dimorphism among the Skorpis. That meant that the third one was either a child or a member of a different species.

I was running out of air. Soon I would have to get up to the surface and fill my lungs. But I dared not move while the Skorpis were so close. Fortunately their attention seemed to be fo-

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cused on the sea bottom. All three of them were looking intently downward as they paddled by.

As soon as they had passed me—by no more than twenty meters—I began slowly rising toward the surface, keeping the heavy buttress between me and them.

The tangy salt air tasted better than wine to me, but I had no time to spare enjoying it. My mind was torn between my original objective of reaching the Skorpis base and a new curiosity about the trio nearby. Where were they going? What were they looking for?

I took a deep breath, then dived back underwater and decided to trail this trio, at least for a little while.

I glided along behind them, watching from a few dozen meters away as they probed deeper and deeper among the jutting underwater structures. They certainly seemed to be searching for something. They inspected the ends of each of the long, tubular structures; spending several minutes examining one before moving off to look at the next. I had to go up to the surface twice while they intently studied the maze of long cylindrical tubes and their supporting buttresses.

I began to realize that many of those tubes had been broken off, smashed at their ends. With all the sea life growing on the structures, that had not been evident at first. But now I could see that some tubes were far shorter than others, and their ends were ragged, as if they had exploded from within or been smashed from without.

At last the Skorpis trio, if that is what they were, swam out to the farthest tube. I dared not follow them all the way out there, for there was no cover to conceal me. The tube extended more than a hundred meters farther into the sea than any of the others. Perhaps it was the only tube to remain undamaged in whatever catastrophe overtook the others. In any event, I stayed close to the protective maze of girders and buttresses that supported the broken tubes.

The trio began to unlimber their equipment as hordes of curious fish swarmed around them, almost obscuring my view of them. In short order I saw the flash of a laser cutter and bubbles of heated water rising toward the gleaming surface above us. All the fish scattered away. They were engrossed enough in their work for me to rise to the surface several times for more air.

After a while the laser flashes stopped and I could hear through the water a cacophony of banging and the screeching of metal on metal. Then a long, tortured groaning sound, like a long-shut door being forced open on rusted hinges. The three of them disappeared from my view.

I waited long minutes. I went up to the surface for air. They were still gone when I came back down.

If that tube actually does connect with the ruins of the city, I thought, this could be a way for the Skorpis to infiltrate the city and wipe out what's left of my troop. Is that what they're up to?

I had to know.

I swam along the length of the tube

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to its end. None of the Skorpis were there, although much of their equipment floated in the water, tethered to the open end of the tube. They had opened it, I saw. They had pried open a small hatch and gone inside. I hung by one hand on the edge of that open hatch and debated my next move. It was dark inside the tube, I could not see much. The three of them might be waiting in there for me to walk into their trap, or they might be half a kilometer down the tube, searching its length to see if it brought them to the ruined city.

Remembering that the Skorpis saw in the dark much better than I could, I still squeezed carefully through that open hatch and inside the tube. I found myself in a water-filled chamber. The walls inside were smooth metal, untouched by the teeming sea life that had attached itself to the outside. I felt panic rising in me unbidden. It was one thing to be underwater in the open ocean. But in this confined chamber something like claustrophobia hit me. The only way out was through the narrow hatch and if it closed and trapped me in here—

My hands, blindly probing the ceiling of the chamber, found another hatch. I pushed against it and it swung upward. The gushing water drew me up through it into another chamber, this one lit a ghostly gray by luminescent walls. I kicked the hatch shut and the water drained out; I could hear the faint hum of pumps at work.

I stood on shaky legs and breathed again. The air was musty, damp, but breathable. Looking around this chamber, I saw still another hatch set into its curving wall. This was an airlock; it had been designed to let people go out into the ocean and come back inside again.

The Skorpis had done so and were somewhere up the tube now. Had they heard the pumps cycling? Did they know I was here? Were they waiting for me on the other side of that hatch?

I slid my laser pistol from its holster and leaned my free hand on the hatch. It swung open slowly. Whoever had designed this airlock had not been worried about enemies invading their city. The hatches opened at a touch.

I peered down the long, straight passageway formed of the tube's interior. It was more brightly lit, its curving walls glowing with luminescence, three sets of wet footprints clearly visible on its metal flooring. I even saw their three sets of flippers, left on the floor a few meters up the passageway.

If they were waiting to ambush me I saw no sign of it. The passageway was perfectly smooth, there were no alcoves or bends for them to hide in. I could see for hundreds of meters along it, but then it rose at a slight angle and I could see no farther.

Should I follow them or wait for them to return? They were far enough up the passageway that they probably did not hear the pumps recycling, so they most likely did not know I was behind them. I could wait here, keeping the hatch slightly ajar. When they returned I could shoot all three of them before they had a chance to

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blink their eyes. They would be dead meat in this featureless passageway; no place for them to hide. They were not even carrying weapons, as far as I could tell.

But they might be scouting out a way for the Skorpis to infiltrate the ruins and surprise my troopers. Frede must have been right; they had put surveillance satellites into orbit and watched us trek to that ancient city. Like spiders watching a band of weary, lost flies. They sat in the center of their web and invited us to come in.

I heard their footsteps before I saw them. Echoing down the metallic passageway, the soft wet paddling of their bare feet came to me. Then their voices, low and rumbling like distant thunder. I pulled the hatch almost completely shut, leaving just a slit open for me to pass through. And shoot through. There was not an atom of cover for them.

Checking my pistol to make certain it was set at its highest level and still fully charged, I waited grimly as they came closer to me and their deaths.

They were talking as they walked down the passageway. I found that I could understand their language, just as I had understood every language I had encountered on all of the missions the Golden One had heaped upon me. I could almost see his smirking expression of superiority, almost hear him telling me gloatingly that he had put the knowledge of the local languages into my brain the way one might insert a list of names and addresses into a computer.

"Another waste of time," one of the Skorpis was grumbling.

The smaller one, in the middle, said in a lighter, softer tone, "Absence of proof is not proof of absence."

The first one growled, "You may impress your fellow scientists with such talk, but all I see is a day spent searching for prey that doesn't exist."

"They exist," said the smaller one. "We're certain of that."

The third one spoke up. "Once I was certain that I could fly with no aid except a certain magical beverage that I had been drinking." His voice was heavy, sorrowful. "I was *very* certain. But I was wrong. Several broken bones showed how wrong I was."

"The aliens are here," said the one in the middle. Her voice sounded like a woman's. A human woman's.

"So you believe."

"We have evidence of their presence," she insisted.

"I am only a warrior, not a scientist. I believe what I can see, what I can touch or smell or hear or sink my teeth into. Your evidence," he practically sneered the word, "is nothing but old myths and the tales of ancient ones."

They were getting close enough for me to see that the smaller of them was a human. A woman. Humans working with the Skorpis? I had thought that the human race was locked in a war for survival against the Skorpis and their allies. How could humans be allied to our enemies?

"We have more evidence than the mythology," the woman said. "And these underwater structures were built for a purpose."

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Neither Skorpis warrior answered her. Yet their silence was more eloquent than further arguing.

They were close enough for me to see clearly now. Unarmed. From the sound of their conversation, they knew nothing about my troopers in the ruins. They were looking for aliens, based on ancient myths.

If I gunned them down it would tell their leaders that enemies were near. When they failed to return to the Skorpis base, others would be sent to search for them. I could not hide their bodies. Sooner or later they would be found. The fact that they came out here unarmed told me that there were no predators in these waters that they feared. Their disappearance would immediately be suspect.

And, truth to tell, I found the prospect of shooting an unarmed human woman more than I wanted to deal with. Besides, I wanted to find out what she was doing with the Skorpis. There was much more going on here than the Golden One had told me.

CHAPTER 9

Softly I shut the hatch. Swiftly I opened the one in the floor and slipped into the water. Closing it behind me, I swam back out into the open sea and used my flightpack to drive myself quickly away from the end of the tube, back to the structures that could hide me.

If the trio suspected that someone else had been in the airlock, they gave no sign of it. They came out, with helmets and flippers back in place, gathered up their tools and swam back toward the Skorpis base. I waited a while, then followed at a more leisurely pace, bobbing up to the surface every few minutes to gulp in air, rather like a dolphin.

There were underwater piers at the Skorpis base, too, but they were far smaller than the ancient ruins. Only two of them, and so new that hardly a barnacle had attached itself to them as yet.

I could see the shadow of a pier built above the water's surface, extending out the same length as this underwater shaft. Cautiously I rose to the surface for a fresh swallow of air. So far so good. I was almost inside the Skorpis base. Almost. It surprised me that the Skorpis had not set out electronic security systems underwater to protect their base from any possible seaborne threat. And the trio I had seen in the water had been unarmed. It was as if they expected no enemy attack, almost as if this was not a military base at all.

And there was at least one human working with them.

The sun was sinking into the sea, throwing a reddish gold glow over the wave tops. I tread water for a while, bobbing up and down as each fresh crest of the incoming tide surged past me. I was close enough to the enemy to hear them walking along the pier above my head, to hear their voices as they worked and talked and complained about their situation the way all soldiers do everywhere, in any era.

"Protecting a litter of humans," one voice griped. "This isn't the life of a warrior."

"Maybe you'd rather have been

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with Second Battalion," said its companion.

"At least they got to use their claws."

"They're all dead. Is that what you want to be?"

"We should've sent in both battalions."

"No, we shouldn't have sent in either one. We should've nuked those hairless apes in the first place, not wasted a whole battalion trying to capture their damnable transceiver."

"Well, anyway, we're struck with guard duty."

"Do you trust 'em?"

"Who?"

"The humans, who else? They say they're scientists, but do you think we can trust them? Or are they really spies?"

"How the hell should I know? They all look alike to me. The gray furs make those decisions."

"Like the decision to try to capture the enemy transceiver."

"Yes. Just like that."

There was more than one human in the Skorpis camp. And they were scientists, apparently. My head buzzed with the possibilities. Perhaps this was the way for me to penetrate further into their camp.

I gave the matter a few moments' thought. No sense waiting until dark. Boldness might work where stealth would be detected.

Hoping that all humans truly did look alike to these Skorpis warriors, I wormed my shoulders out of the flightpack harness and fastened it to the underside of the pier. With some feelings of trepidation, I also unbuckled my gunbelt and left the laser pistol and knife there, as well. Then I reached up, grabbed the edge of the pier, and hauled myself up out of the water.

"Who the hell . . . ?" The two Skorpis on the pier were evidently sentries. Each of them had a rifle, which they immediately unslung from their shoulders and pointed at me.

"Identify yourself!" said the larger of the two. Both of them were enormous, towering above me in height and twice my bulk.

"Orion," I said, trying to smile disarmingly. "I got separated from the others and just made it back."

"I've never seen you before."

"Just arrived a few days ago," I said.

"There's been no resupply mission here for months," said the Skorpis. Both their rifles were pointed at my chest.

Drawing myself up on my dignity, I answered as haughtily as I could, "I was brought here on a special flight, at great expense. At least your superiors recognize the value of a scientist, even if you don't."

They looked at each other. It was difficult to read the expression on their feline faces, but to me they seemed uncertain, fully suspecting that I was lying through my teeth but unable to be sure. Then they did what all soldiers in every era do when in doubt: they marched me to their commanding officer.

Thus I was trooped from one giant Skorpis to another, from the pier to the command post at its base, from the command post to the quarters of

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the officer of the guard. From there to the offices of the chief of security, where a Skorpis wearing a chestful of ribbons on a cinnamon-colored uniform eyed me with enormous suspicion from behind an airport-sized desk. There are no obvious gender characteristics among the Skorpis, at least none that I could detect with their uniforms on, but I knew from my briefing information that this security chief was a female, as all Skorpis officers were.

"You come out of the sea with no clothes, no equipment?"

I must admit that I did feel slightly foolish standing in front of her with nothing but a pair of shorts that were still dripping wet. "I am with the human scientists," I said with as much dignity as I could command. "I was simply swimming near the base to check the structures that have been built underwater."

"And you claim that you arrived three days ago."

"Yes, that's right."

"There has been no flight into this base since the fleet departed after the battle several weeks ago," she growled at me.

"Take me to my fellow scientists," I insisted. "They'll vouch for me."

"There has been no flight in here for several weeks," she repeated.

"There was one. Perhaps you were not informed about it."

"That is impossible. Who are you and where are you from?"

I kept insisting that she take me to the other human scientists. She studied me the way a cat studies a bird chirping on a limb, just out of reach.

"The only other humans on this planet were the assault team that was wiped out. Perhaps we didn't exterminate all of you. . . ." There was a heavily-gouged square of wood on her desktop. Unconsciously, she scraped the unsheathed claws of one hand along it. Or was it unconsciously? I got the impression she would like to use her claws on me.

I continued my bluff. "If you'll simply let me see my fellow scientists, I'm certain that all this confusion can be cleared up."

She shook her head in a very human negative.

"What harm could it do?" I coaxed. "One single human, unarmed, in the midst of a whole base full of warriors?"

"You could be carrying an explosive device inside you. You could be an android. A walking bomb. The humans are very clever that way."

I shrugged carelessly. "Examine me, then. Probe me with search beams."

"You've already been probed," she replied. "While you've been standing here."

"Have you found any explosives? Anything at all but normal human organs inside a normal human skin?"

"You humans are very clever," she muttered again.

After nearly an hour of stubborn intransigence, she finally decided to march me personally—with a squad of six fully-armed warriors escorting us—to the part of the base where the human scientists were quartered.

"They sleep at night," she said disdainfully as we walked through the

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camp. It was bustling with activity, much as a human camp would in early morning. "This will disturb them."

It seemed to me that she did not mind disturbing the humans. Not in the slightest.

The humans were in a compound separated from the rest of the base by a fence of energy beams. The Skorpis guards snapped to spine-popping attention as the officer approached. They turned off a section of the fence for us to walk through. The officer ordered our escort to remain at the fence. "Come if I call you," she commanded them. They saluted as one single organism.

It was quiet inside the human compound. Most of the buildings were dark, although lights showed through the windows of one long low-roofed structure.

"The humans eat their meals together," the officer muttered, from somewhere in the darkness over my head. "They eat plants and pastes made by machines." Her voice reeked with distaste.

I was tempted to tell her that some humans hunt for their meals. But I refrained.

Without knocking she opened the door to the mess hall—for that is what it was—and stepped inside. Floorboards creaked under her mass. I came in behind her.

Twenty-two men and women, each of them in drab coveralls, stopped eating and turned to stare at me, spoons and forks in midair, mouths open and eyes wide with surprise.

The officer grabbed me by the scruff of the neck and nearly hauled me off my feet.

"This one says he belongs with you," she said, loud enough to rattle the windows. "Does he speak truth?"

A bearded man at the head of the table swallowed hard enough for me to see his Adam's apple work up and down.

"He belongs with us, yes," he said in a high, surprised voice.

The officer let go of me.

"When did he arrive? How?"

Before they could give a story that contradicted mine, I rattled, "On the special flight several days ago, just as I told you." Desperately I hoped that none of the other humans would give me away.

"I know of no special flight."

"It was only here very briefly," said the man at the head of the table.

"You might have been out at the perimeter," one of the women added, in a voice that trembled slightly.

"I can check all incoming flights in our computer records," said the officer. "If he is lying, he will die. If you help him lie, you will die with him."

The bearded man at the head of the table got to his feet. "You can't threaten us so easily. We were sent here by the Hegemony high command. The work we have to do here is too important to the progress of the war for us to be bullied by Skorpis warriors."

The officer hissed at him, just like a spitting cat. Then she said, with murderous calm, "The Hegemony orders us to protect you. If this human is a spy or a saboteur, he must be dealt with. If you help him, you are work-

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ing against the Hegemony and you will be dealt with also."

"Let us take care of him," the bearded man said. "He's no threat to you or anyone else."

"You vouch for him? He is a scientist, as you are?"

The man started to nod, but one of the women down the table burst out, "We never saw him before! We don't know who he is!"

"Randa!"

"It's no good, Delos," she said to the bearded one. "What we're trying to accomplish here is too important to allow some spy to wreck everything!"

"You say he is a spy?" the officer thundered.

"None of us ever saw him before!" Randa fairly screamed. "Take him away. Open up his brain and find out who he is and why he's here!"

CHAPTER 10

Everyone in the mess hall froze, frightened, faces contorted with shock and uncertainty. Even the huge Skorpis security officer stood stock-still for a moment, just as stunned with Randa's revelation as the other humans.

In that flash of a moment I acted. It was either move or die, and I had no intention of dying.

I spun on the ball of my foot and punched the security officer as hard as I could on her chin. She staggered backward, knees buckling. Before she could recover I bolted across the mess hall, vaulting clean over the table while several of the humans shrieked, and hurled myself through one of the windows. I crashed through and landed head-first on the hard-baked ground outside. I could hear the security officer bellowing like a lioness in heat as I rolled to my feet and ran for the energy fence that enclosed the human compound.

It was more than two meters high but I cleared it with room to spare. Fear augments athletic skills. Now I could hear shouting behind me as I raced through the square tents and more permanent structures of the Skorpis camp. There were plenty of the huge warriors in sight, working, digging, marching in the darkness of the night. They seemed more surprised than alarmed as I sprinted past them, heading for the beach and the sea.

I knew the officer I had slugged would radio her security detail to head me off. And sure enough, I could see teams of warriors bustling out of the buildings at the base of the twin piers up ahead. More shouts behind me and a laser bolt crackling bright red lanced past my ear. A warning shot. They won't try to kill me, I reasoned. They want me alive for questioning. But that didn't mean they wouldn't gleefully burn my legs off.

I dodged behind one of the metal prefabricated buildings and started running off at a tangent to the beach. The piers were out, too well guarded. But if I could get to the water perhaps I could wait a while, then swim back to the place where I had stashed my flightpack and weapons. If the Skorpis did not find them first.

As I bolted around the corner of another building, angling off toward

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the beach once more, a team of six Skorpis suddenly loomed ahead of me, all of them armed with rifles. I gave them no chance to aim at me. I dived into them with a rolling block, barreling into their legs, knocking several of them down. My senses were in overdrive, and I saw them tangling each other's arms and legs, cursing and snarling as they tried to pull themselves loose and get at me. I grabbed the rifle out of the hands of one of them, clubbed him to his knees with its butt, then flipped it around and fired into them point-blank.

I had no time to see how much damage I had done. Leaving them writhing on the ground I dashed off toward the beach once again. To my left I could see a squad of Skorpis running along the sand in my direction. I had to get to the water before they saw me.

Too late. They saw in the dark much better than I did and they quickly fired several rifle blasts at my feet, puffing up gritty pebbles and sand. I skidded to a stop and they ceased shooting and came running toward me.

I fired from the hip, one-handed, and knocked the closest two of them down. Then I flung myself face first on the ground as the rest of them dropped to their knees and shot back at me.

There was no time for a fire fight. If they pinned me down here for more than a few moments the whole Skorpis base would be upon me. I had no choice. I leaped to my feet, firing as I ran, and raced for the water as fast as my legs would carry me.

My firing made them duck their heads a bit, but before I had taken a dozen strides a laser bolt seared my hip. I spun around, staggered, then dove on toward the water. Clamping down on the blood vessels, shutting off the pain signals, I limped toward the sea, only a tantalizingly dozen or so meters away now.

Another bolt hit my leg and I flopped down, rolled, and used my rifle to haul myself up again. I hopped, hobbled, staggered for the water as the Skorpis warriors came running toward me.

"Alive!" I heard one of them yell. "Take him alive!"

That was my one hope. I shot two more of the warriors as I tottered for the water. More laser blasts hit me, in the legs, in the chest. They were no longer worried about preserving me for interrogation; I was hitting too many of them.

I splashed into the surf, still firing, still being hit. Despite my rigid self-control I felt as if my legs had burned off. Another bolt burned my shoulder so badly that I dropped the rifle. It hissed as its hot barrel struck the water.

The world was spinning. The surf surging against my bloodied legs knocked me over as more laser blasts lanced past my head. They were shooting to kill.

I crawled into the waves, letting the water surge over me, cool and stinging with salt. Like a crab I scrabbled along the sandy bottom as the water flowed over my head, covering me, protecting me from their merci-

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less lasers. I tasted salt water in my mouth, felt it filling my nose. I was deep enough now to float up off the bottom and let the current carry me out farther from the land.

There was not much skin on me that was unburned, I knew. Despite my control of the pain signals, my body was telling me that it was almost gone. Legs useless, one arm burned to the bone, another searing wound in my chest.

I floated to the surface and gulped cool night air. I did not have the strength to swim. I was going to die again, and this time I knew that the Golden One had no intention of reviving me. I had failed in my mission. Failed him. Failed myself.

I would never see Anya again. Never look into her gray solemn eyes. Never feel her touch, hear her voice.

The Golden One had abandoned me to die here on this miserable planet. They had all abandoned me, all the Creators. Even Anya.

A bitter torrent of regret surged through me. Somewhere deep in my mind I could hear Aten's scornful laughter telling me that he knew I would fail him. I was merely a creature, after all. How dare I presume to love one of the Creators? I was made to be their tool, not their equal.

Regret. Love for Anya. Hatred for the Golden One. All these emotions flooded through me as I bobbed in the swells of that unnamed ocean, dying.

And something else. Something that I had never realized existed within me came to the front of my consciousness. Me. Myself. The individual who is Orion. Not the slave of the Golden One. Not even the lover of the goddess Anya. Myself. It did not matter how I was created or by whom. It did not matter whom I loved or who loved me. I exist. I live and breathe and love and hate. I will not tamely die, mourning my failures, bemoaning my fate.

I pulled what little strength was left in my battered body and concentrated every atom of my will. There are paths through space-time, I knew. The continuum is like an ocean, and there are currents in it that can carry you from one place-time to another.

Squeezing my eyes shut, I thought back to all the times I had been translated through the continuum of space-time. Could I move myself voluntarily? Could I reach that city of the Creators, the city I had saved from Set's destruction, the city that they kept safe in its own protective bubble of energy?

With my eyes tightly closed I could not see the stars in the night sky. My body grew cold, numb. I no longer felt the bobbing of the sea. Colder I grew, cryogenically cold for an endless moment.

And then I felt the warmth of sunlight on my naked skin. I opened my eyes and found myself lying in a meadow on a hillside. And below me lay the magnificent city of the Creators beneath its radiant sphere of energy, rising beside a calm blue sea.

A city of monuments and heroic statues, all dedicated to the Creators themselves. Pyramids and temples from every era, every culture of Earth. A city empty of people, except for

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the handful of Creators, the self-styled masters of the human race who had allowed themselves to be worshipped as gods. They had translated the monuments that adoring humans had built to them, accumulating them into this glowing city devoted to their own gratification.

I rose to my feet. My body was whole and strong. The breeze from the sea was cool, the sun high overhead warming. I walked through wildflowers down the hill toward the city. Deer bounded in the woods farther off to my right. Rabbits hurried through the grass at my feet, stopping now and then to stare at me, noses twitching.

The city was empty. I knew that there were robots and mechanical conveniences waiting to be summoned by mere thought. But the Creators were not there, not one of them. I felt disappointed, yet not surprised. Aten had told me that they were scattered among the stars, struggling to resolve this ultimate crisis that they faced. Yet, to beings who can come and go through spacetime at will, why were none of them here in their home base at this particular nexus in the continuum?

I wandered on, asking myself what I expected of this visit and getting nothing but a vague sense of uneasiness by way of an answer.

Past the Mayan Temple of the Sun I strolled, alone in the ageless city. Past the Parthenon and the great golden reclining Buddha that seemed to be grinning at me, knowingly. I walked through the city from one side to the other until I was at the base of the massive pyramid of Khufu, out beyond and Colossus of Rhodes.

I turned the corner of the great pyramid and there was the ocean, clean and glittering beneath the sun, waves washing up on the beach with curls of froth as they broke gently against the sand. The sea called to me and I walked into it, wading up to my hips before I slid in and began swimming slowly out toward the distant horizon.

"Welcome, friend Orion," said a dolphin that popped up beside me. "We are happy to see you back among us."

"Back among you?" I asked.

I saw that I was surrounded by the grinning sea mammals, gray and sleek and each as big as five men or more. It was no surprise to me that I understood their clicks and whistles. But I was surprised that they understood my tongue.

"It's been a long time since we hunted the fast-darting tuna together," said the nearest dolphin.

"Or went diving to the lair of the giant squid," said another.

"Where are the Creators?" I asked. "Do you know?"

"The other two-legs? They have been gone for long ages, Orion."

"They aren't much fun. They argue among themselves most of the time."

"They forget that we can hear them. Our sense of hearing is very acute."

"I know," I said, grinning back at them as I treaded water.

"Come!" said the nearest one. "There's a whole school of tuna not more than five kilometers from here.

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Let's feast on them!"

"Wait!" I begged. "I can't swim that far."

"No need for you to swim, friend Orion. Ride on my back the way you used to so many tides ago."

"If you don't mind carrying me. . . ."

"Of course not! One hunter to another, we are all friends here in the sea."

So I slid one leg across his smooth back, and clutched his dorsal fin with both my hands, and off we went on a wild splashing ride. The dolphin racing powerfully, smoothly through the ocean, dipping down below the surface to run as fast as possible, then sliding up to blow steamy stale air through his vent and pull in a gulp of fresh air with a wet sucking noise. I did the same each time he popped to the surface. If the individual dolphins had names I never learned them; they seemed to know each other without the need for such tags.

They said I had gone hunting with them before, that we were old friends. I had no memory of it whatsoever, but I did not let that interfere with my enjoyment of this wild splashing ride through the ocean. The water was clear as air down to a considerable depth, with the sun lighting it up. If it weren't for the bubbles and the swarms of colorful fish darting all around us I would not have thought we were underwater.

And then would come the splashing, frothing moment of breaking the surface, taking the fresh gulp of air. And then down below we would go again, sliding along smoothly on the powerful strokes of their tails.

Soon enough we came to the tuna school, big silver-gray sleek speedsters who turned and fled at the approach of the tribe of dolphins. Fast as the tuna were, though, the dolphins were faster. We split up into several smaller groups, circling around the school of tuna to set up a trap, much as the Mongols did on their great hunts each year. I slid free of my mount and hovered with a few of the older dolphins, treading water as I waited for the circlers to drive the prey towards me.

"Don't let them get past you!" my friend clicked gleefully as he dashed off. Underwater, I could not reply.

The tuna panicked and tried to evade the trap. The dolphins snapped them up in their grinning jaws by the dozens, by the hundreds, gulping them down one after another. I grabbed one, more than enough for me to handle, bit through its spine to kill it and then let myself float to the surface with the big fish in my hands.

"Only one, friend Orion?" my friend teased. "This is the mighty hunter?"

I laughed as I tore at the clean fresh meat of the tuna. "How many deer can you chase down, legless one? How many rabbits can you outrun?"

I saw the dark fins of sharks circling in the distance, attracted by our slaughter of the tuna, but they kept away from the dolphins. As the sun began to slide toward the sea, we swam back to the beach by the Creators's city, with me riding my friend's back again.

Finally I was wading toward the

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beach. I stopped while still waist-deep in the water and shouted a farewell to the dolphins.

"Thanks for the hunt," I called.

"The sea is good, friend Orion. Too bad you aren't a dolphin, or at least a whale. You are a good companion, for a two-leg."

"And you are good friends, all of you. Thanks for sharing your hunt with me."

"The sea will always be your friend, Orion. It is good in the water."

With that, they turned and headed out to the deeper waters, leaving me to stagger back up the beach and throw myself on the warm sand for the lowering sun to dry me.

The sea will always be my friend, they said. Yet there was a place in spacetime where I was floating helpless in the sea, wounded and dying.

I returned to that place.

CHAPTER 11

I had hoped that I could somehow return with my body repaired, strong and healed of my wounds. But that, I could not do.

I opened my eyes and saw the starry dark night and felt pain, wave after wave of agony throbbing through every part of my body. Even as I consciously damped down the pain receptors in my brain I could feel it sullenly glowering beneath my deliberate self-control.

I was floating on my back in the deep, dark ocean, just as battered and helpless as I had been before my trip to the Creators's realm. Had I really been there, cavorting with dolphins? Or was it all an illusion, a self-imposed dream, a feverish attempt at escapism?

My self-questioning quickly ended. I felt something brush against my badly burned leg. Just a touch, enough to make me twitch with alarm and get a mouthful of salt water in return. Then it was gone. But it would be back, I knew.

I remembered those tentacled horrors in the swamp, and wondered what predators this ocean harbored. Alone, half-dead, weaponless, I was going to be easy prey for some hungry hunter.

The sea will always be my friend, the dolphins had told me. I doubted it.

Another touch, making me flinch again. I remembered that sharks will often nudge their prey, bump it, almost play with it like a cat with a mouse before snapping it up in those horrendous tearing teeth.

Should I play dead or try to swim away? Would it make any difference?

It was no shark. This time I felt a tentacle delicately wrapping itself around the burned remains of my ankle. I shook my leg and it let go.

But not for long. The tentacle came back at precisely the same spot. This time it held fast. Quickly another slithered across my chest. I could feel its suckers attaching themselves to my burned flesh, delicately, almost tenderly.

I knew it was hopeless but I gulped down a big swallow of air as the tentacles pulled me below the surface. Bubbles gurgled in my ears. We sank down into the cold inky depths of the ocean.

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Do not be afraid, friend Orion. I heard in my mind. *We will not hurt you.*

Now I'm hallucinating, I told myself. First I dream about dolphins and now I hallucinate that I can hear their voices in my mind. While I'm being pulled down to the bottom of the sea by some tentacled monster. If I don't drown the pressure will cave in my ribs soon enough.

Have a little faith, friend Orion, the voice in my mind said. It felt almost amused.

I lost track of time as we sank deeper and deeper into the sea. There was no light to see by, no sensation at all except the rush of water swirling by me.

Listen to the music of our world, said the voice. *Open your mind to it.*

I could hear more than gurgling, I realized. There were crackling sounds all around me. Hoots and whistles and soft thrumming noises. And off in the distance a faint melodic crooning that rose and fell. None of the clicks and whistles of dolphins, though.

Now open your eyes, Orion.

I hadn't realized I'd been keeping them shut. Involuntarily I gasped. I was surrounded by hundreds of soft glowing points of light, like being in the middle of a meadow full of fireflies or in the heart of a cluster of gleaming stars.

And when I gasped I had air to breathe.

"Can you hear me?" the voice asked. And I could. It was using sound rather than telepathy or whatever form of mind contact it had used before.

"Good," it said, without my answering. "The air globe is stabilized and you should feel more comfortable. We will see what can be done about your wounds." The voice was silky soft, warm and calm.

"Who are you?" I asked. "Where are we?"

The lights danced and twinkled around me, blue and red and green and yellow, but I could not make out any shapes.

"We are nearing the bottom of the sea, roughly a hundred kilometers from the shore where the Skorpis have made their base."

"You know about them?"

I sensed a tolerant chuckle. "Yes, we know about them. And about you." The voice grew darker, more severe, "And about the way you casually slaughter one another."

"I wouldn't call it casual," I replied.

No response. The lights flickered around me, as if they were dancing in a sphere all around me, binding me in a web of blinking colorful flashes of energy.

"You haven't told me who you are," I said.

"You may call us the Old Ones."

"What does that mean?"

Again that tolerant sense of amusement, like a grandfather watching a baby's hesitant first steps.

"You will find out in due course," the voice said. "For now, we must travel deeper into the sea."

I got a sense of motion, acceleration, a tremendous rushing through the dark waters. The lights remained all around me. I could breathe. I seemed to be floating weightlessly, al-

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most like an astronaut in orbit. In the dim flickering light I could see my wounds were scabbing over. The bleeding had stopped completely and I felt a little stronger. All the while I was moving through the inky depths, speeding deeper and deeper, farther and farther from the shore.

At last I saw more lights approaching. They glowed and pulsated as if they were living, breathing creatures. Whole avenues of light opened up before my eyes, as if I were flying toward a vast city, swooping along a highway of lights that led to its magnificent heart.

"How do you feel?" the voice asked.

"Bewildered."

"I mean physically. Your wounds."

I flexed my arms, looked down at my legs. They were healing rapidly.

"Everything seems to be going along fine."

"Good. We are pleased."

"Tell me more about yourselves. What is this city of lights that we are approaching?"

"This is our home, Orion. The home of the Old Ones."

"May I see you?" I asked, sensing that these lights were merely sparks of energy.

"You may be unpleasantly surprised," the voice replied. "You may be repelled by our appearance."

"Then tell me what to expect."

"A reasonable approach to the problem." The voice hesitated, as if checking with others before answering my request. Then: "Orion, your Creators have told you that space-time is an ocean, have they not?"

"The one called Aten has taunted me more than once about my linear perception of space-time," I answered.

"Yes, we can see that. Yet your linear perception is not entirely in error, Orion."

"There are currents in the ocean of space-time," I said.

"And there is a flow, a very definite flow. Time's arrow exists. Entropy exists. Even though we may move back and forth across the ocean of space-time, we still cannot hold back entropy. The continuum unravels a little whenever we move through space-time. The greater our move, the more disorder arises."

"But what has this to do with the way you look?" I asked.

"Time's arrow," the voice replied. "There are earlier times and later times. There is a point in space-time when your planet Earth is barren and lifeless. There is a point where the human race begins—"

"Built by the Creators and sent to destroy the Neanderthals so that Earth can be inhabited by the Creators's creatures."

"Who in turn, over the millennia, evolve into the Creators themselves."

"Yes. They created us and we created them."

"There is a point in the evolution of our kind," the voice said, "when we had not yet developed intelligence, when we were far simpler beings living in the seas of our original world."

"Lunga is not your original world?"

"Oh, no. Not at all."

"Then where did you originate?"

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I sensed a hesitation. "Does it matter? Suffice to say that once we were far simpler beings than we are now."

"Simpler beings," I said, beginning to understand what he was hinting at, "with tentacles?"

"Yes."

"And claws that can crack armor?"

"Do you think you are prepared to see us?"

I thought of those things in the swamp, with their clutching tentacles and snapping claws and dozens of beady eyes.

I took a breath and said shakily, "Yes, I'm ready."

"Very well."

The sea around me brightened and I saw that I was surrounded by dozens of writhing tentacled creatures. They were huge, immense, like gigantic pulsating jellyfish with long wriggling tentacles and lipless round mouths that opened and closed, opened and closed, coming nearer and nearer to me. My skin crawled and I felt panic rising inside me, surrounded by these enormous engulfing undulating horrors pressing closer and closer, tentacles reaching out for me, mouths pulsating. . . .

"Can you rise above your fears, Orion?"

I wanted to scream. Those enormous gaping mouths, like suckers big enough to swallow me whole, they seemed to be bearing down upon me, coming to devour me, coming to grasp me in those gaping maws. I could feel their digestive fluids burning into my flesh. I felt smothered, suffocating.

"Can you see beyond your terror, Orion? Can you look upon us as we truly are?"

I realized my eyes were squeezed shut, my fists pressed so hard against my temples I thought my skull would burst. They saved you! I raged at myself. They're healing your wounds. They are intelligent beings. Go beyond their appearance; look at them as they see themselves.

Shaking with dread, I opened my eyes and forced myself to look at them again. They hovered all around me, huge, engulfing. I took a deep, shuddering breath. They came no closer, floating silently in the deep waters. Yet they were so enormous that they filled my vision wherever I looked. There was no escaping them. I fought against the panic that surged through me, deliberately forced my heart to slow its terrified beat, calmed my breathing to something close to normal.

I stared at them for long, long minutes. They hovered all around me, pulsating slowly, lights flickering within their undulating bodies, patterns of color glowing and shifting rhythmically across their translucent skins. There was a certain dignity to them, I slowly recognized. Even a certain kind of beauty as they floated throbbing in the deep waters. They moved gracefully, I forced myself to admit, trying to avoid looking at those dilating mouths.

And they were watching me intently. Each of them possessed two giant, solemn eyes that seemed focused on me.

"You are . . . beautiful," I managed to croak.

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"We are glad you think so. After your experience in the swamp we were afraid that you would be biased against us. Xenophobia is one of the deepest traits of your species."

"We were created to be warriors," I replied. "It makes it easier to kill your foes if you are frightened of them."

"And yet the dolphins vouched for you."

"The dolphins?" I blurted. "Are they here?"

"Not in this era," the voice answered.

I realized that these Old Ones could travel through time the way the Creators could. The way I had myself.

"When we first made contact with you, Orion," the voice continued, "we sensed nothing but a warrior intent on slaying his enemies. But the dolphins told us you were a good friend to them, so we probed deeper."

It was the Old Ones whom I had sensed earlier, then. Yet I had no memory of how I got to be a good friend to the dolphins. Was I sent on a mission into the ocean, in another era?

"We find that although your basic instincts are those of a warrior, there are other desires struggling within you."

"I have a will of my own," I told them, "even though my Creator looks upon me as nothing more than a tool for his use."

"That is a part of the problem you present to us." The voice sounded slightly perturbed despite its silky smoothness. "We have been observing your kind since you first arrived. You humans are bloodthirsty as well as xenophobic."

"We were made that way," I admitted. "Although some of us have tried to rise above it."

"Have you?"

"Some of us have. There are humans at the Skorpis base who are scientists. They are not warriors, not killers."

"Why do you not regard the Skorpis as humans?" Although I heard only one voice, I got the impression that more than one of these sea creatures was speaking to me, or perhaps they were all speaking, and what I heard was a blend of their individual thoughts and questions.

"The Skorpis come from another world," I answered. "They are descended from felines."

"While your kind are patterned after primate apes."

"That's right," I said.

"What makes you think that the Skorpis come from a different origin than your own?"

"They couldn't. . . ." I hesitated. "Do you mean that they were also—"

"Produced by your Creators? Why do you find that difficult to believe?"

"Not difficult. Just—a new idea. I hadn't considered it before."

"The Universe is old, Orion. And your Creators have been very busy."

"But if the Skorpis were also made by the Creators, why are they fighting against us?" I asked.

"Whatever your Creators touch degenerates into violence," the Old Ones said. "They are a plague among the stars."

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"But you," I asked again. "Who are you? What have you to do with the Creators?"

"We are a very old race, Orion. Older than your Creators by tens of millions of years. We have no desire to be dragged into the slaughter that your kind are perpetrating."

"Why should you be?"

"Because your fellow humans have discovered us. They have tried to make contact with us. They want us to ally ourselves with them against their enemies."

"I don't even know who our enemies are," I said.

"Other humans, of course. And species of similar levels of development, such as the Skorpis and the Tsihn."

I felt confused, stunned almost, at all this new information they were throwing at me. They sensed my mental turmoil.

"Do not feel anxious, Orion. We will explain everything to you so that you can understand it fully."

Why? I wondered. What do you want?

As if in answer, the silky voice told me, "You are going to be our ambassador, Orion. You will give our message to your Creators."

CHAPTER 12

The city of the Old Ones, down at the abyssal depths of the ocean, was a vast wonderland of delights. Actually, to call it a city is a misnomer, for the Old Ones had no need for buildings or structures. Yet they clustered together in this sea bottom aggregation of lights and patterns, exchanging thoughts like very old and very wise philosophers. Aristotle would have been happy here; Plato would have found his republic of intellect.

For countless days I wandered through the city, buoyed in an invisible sphere that somehow always was filled with fresh air. I neither ate nor drank, yet I was nourished and refreshed. My wounds healed completely as I learned of the Old Ones, their origins and history, their place in the continuum, their relationship to the Creators and the war that was spanning this region of the Galaxy.

The Old Ones had evolved from octopus-like invertebrates living in the early seas of their home planet. We humans have a prejudice that a species cannot become fully intelligent until it masters energy sources beyond its own muscular power. For a land-dwelling species such as ourselves, that first energy source was fire. Since fire is impossible underwater, we tend to dismiss the possibilities of intelligent sea creatures. Even the dolphins would not have reached true intelligence if human scientists had not augmented their native brains.

The Old Ones had manipulating organs: ten tentacles that could grasp and maneuver as well as human hands or better. They had large, intelligent brains and exquisitely subtle sensory organs. Instead of fire, they developed the abundant electrical energies they found in many species of fish and eels. Where we humans built tools and learned engineering, the Old Ones learned biology and incorporated the living forms they needed into a symbiotic existence within

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their own bodies.

They learned about the world around them. Over the millennia, over the eons, they slowly built up a body of knowledge about the sea and, eventually, the land and even the sun and stars. Long before the dinosaurs ranged across Mesozoic Earth, the Old Ones discovered the energies of spacetime and learned how to move through the continuum.

By the time the primate apes of Earth began to develop into the earliest hominids, the Old Ones had explored the Galaxy. By the time Aten and the other Creators decided to build their human tools and send them to the Ice Age strongholds of the Neanderthals on a mission of genocide, the Old Ones had decided to remain to themselves, content to contemplate the Universe without tampering with it.

Where we humans, driven by our Creators, are constantly meddling with the flow of spacetime, constantly trying to alter the continuum to suit our needs and desires, the Old Ones have withdrawn to their oceans and their thoughts. They are to us as a giant Sequoia tree is to a chittering squirrel.

All this I learned from them.

"Friend Orion," said the silky-voiced one to me, "the moment has come for you to return to your own kind."

The Old One who addressed me was swimming alongside my sphere as we gently glided through an avenue of blue-white lights that flickered like fireflies through the dark water. In all the time I had spent with them I had never heard any of the Old Ones refer to one another by a name. They had no need of names, it seemed. I could tell them from one another by differences in their coloration and in the sound of their voices, although I never did learn how they produced sounds that I could hear.

"You know now who we are and what we are," said my companion and teacher. "Please tell your Creators that we refuse to be drawn into their slaughters. Our only desire is to live in peace."

"But what if one of our warring groups tries to force you to join their side?"

Again that sense of gentle amusement. "We will not be forced, Orion. We will not listen to their words. If they try to use weapons against us, their weapons will not function. We threaten no one. We will harm no one. But we will not allow our knowledge or strength to be used in war."

I recognized the hint.

"Will you meet us if we stop fighting? Would you be willing to exchange thoughts with us if we stop the war?"

A feeling of wry humor touched me. "Perhaps, Orion. In a million years or so, perhaps then you will be ready to share thoughts with us."

I felt myself grinning. "That's something to look forward to."

"Farewell, ambassador Orion."

I found myself sprawled on the beach near the ruins of the ancient city, where I had left the rest of my troopers. How long ago? I had no idea of how much time had passed. It was

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daylight, close to midday, I judged from the height of the blazing sun.

Getting to my feet, I started walking rapidly across the glaring sand toward the ruins. Within minutes a voice from one of the crumbling walls hailed me.

"Captain? Is that you?"

"Yes," I said, stating the obvious.

The trooper climbed up atop the broken edge of the wall. I recognized him: Jerron, the smallest man in the unit, often teased as the runt of the litter. He glanced behind him, and made a slight pushing motion with both his hands. I realized that his hands were empty. He was unarmed, not even a pistol on him.

I was about to ask him why he had no gun when a quartet of Skorpis warriors rose beside me. They were all fully armed. They pointed their rifles at me.

"Surrender or be killed."

The nearest bit of cover was the wall on which they stood. Otherwise I was totally unprotected, standing out on the bare beach in the noontime sun, wearing nothing but a ragged pair of shorts. Not even much of a shadow with me.

I surrendered.

"They came in the second night you were gone," Jerron told me as the Skorpis warriors marched us across the beach toward their base. "Just popped up in the middle of the ruins, outta nowhere. We never had a chance."

So the Skorpis had found that the underwater tunnels led into the heart of the ruined city, I realized. They knew we were there and they used the tunnels to take the troops by surprise.

"How bad were our casualties?" I asked.

"It all happened so fast we never had much of a chance to put up a fight. The guys on sentry duty caught it. Manfred, Klon, Wilma."

Manfred. The sergeant I had forced to become a lieutenant. A real lieutenant would not have been on guard duty. Manfred's old habits killed him. Then I remembered Frede warning me that it's not smart for a soldier to make friends. Manfred was hardly a friend, but I felt his loss as if it were my own fault.

"How long have I been away?" I asked. "I've lost track of time."

"Four days, sir. The Skorpis knocked us off the second night you were gone, and then they've been waiting for you to come back ever since."

"So now they've got us all."

"Sorry to be the judas goat, sir." Jerron looked fairly miserable as we walked, struggling to keep pace with the giant Skorpis's strides. They were quite willing to nudge us with their rifle butts if they felt we were lagging behind.

"You've done nothing to be ashamed of, soldier," I said. "This whole mission was a disaster from the outset."

They marched us through their perimeter emplacements and into an open compound in the middle of the base, sealed off by electric fences, guarded by a dozen heavily-armed warriors, surrounded by all the Skorpis on the planet. They were in-

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tent on keeping us from escaping, I could see.

Lt. Frede hurried to me as soon as the warriors pushed little Jerron and me into the compound.

"Orion! Captain! Are you all right?" There was real concern in her eyes.

"I'm unhurt," I said.

"From what we had heard, the Skorpis had fried you six ways from breakfast."

"They exaggerated their marksmanship," I said.

Lt. Quint pushed through the group that had gathered around us. "They claim you killed half a dozen of them," he said, with something like admiration in his voice.

"I didn't stop to count."

Frede said, "I don't know what they intend to do with us, but it won't be pleasant."

"How have they treated you so far?"

"Oh, OK, by their standards. We're stuck in this compound. No shelter. When it rains we get wet. We sleep on the ground. They feed us once a day, towards sundown."

"I haven't missed today's feeding, then."

Her expression grew more serious. "It seemed to me they were waiting for something. I guess they wanted to get you. Now they've got all of us."

Quint added, "Now they can do whatever it is they intend to do."

"Did you know there are other humans in this camp?"

"Others? No!" Frede said.

"I haven't seen any," said Quint.

"They seem to be scientists. And they're working with the Skorpis."

"Willingly?"

"I don't know."

"You there!" a deep Skorpis voice bellowed. "The one called Orion. To the gate. *Now!*"

I went to the gate, my officers and most of the remaining troopers trailing after me. The one who had called me was the security officer. I recognized her face and the insignia on her cinnamon brown uniform.

"Take him out of there," she commanded the guards. "I have a few questions I want him to answer."

I shot a glance back to Frede and the others. "Guess I'll miss today's meal, after all."

They marched me to the security officer's office and sat me in a chair that was a size too big for me.

"At least your uniform is dry this time," the security officer growled as she sat behind her desk. Two big guards stood behind me. My "uniform" was still nothing more than the shorts I had been wearing since she had last seen me.

"The other humans know nothing of you, even though some of them were willing to lie on your behalf."

"They are scientists," I said. "Not warriors."

"And you?"

"I am a warrior."

"Why did you come here?"

"To this planet? To set up a base from which we could attack you."

"And after your base was destroyed, why did you try to infiltrate this base of ours? One human, alone?"

"My orders were to destroy your base. I was scouting to see how I could accomplish that."

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"Scouting alone?"

"Yes."

"And you intended to attack this base with fifty-two warriors, no heavy weapons, no support?"

"Yes."

She glared at me out of her yellow cat's eyes. "I don't believe you. Not even a human would be so stupid."

I temporized. "I knew you had nuclear weapons here. I thought I might set one off and wipe you out."

"And kill yourself doing it."

With a shrug I replied, "You're going to kill me anyway. What difference does it make?"

She radiated suspicion. "You came to this camp to make contact with the other humans. At least some of them are traitors, working against us. You will tell me which ones they are."

I shook my head. "I didn't even know there were any humans here when I infiltrated your camp. It was a shock to me. I still don't know what they're doing here."

"I don't believe a word you say."

"You have lie-detecting equipment, don't you? Or truth serum?"

Slowly she raised one hand and unsheathed her claws. "I can get the truth from you with these."

"You have the truth from me," I said, trying to remain calm. "No matter what you do the truth will remain the same."

"We will see." Then she added, in a growl, "You struck me. Then you ran away. Such a disgrace must be avenged."

The two guards grabbed my arms and twisted them painfully behind my back. The security officer rose from behind her desk, holding her hand full of claws in front of her like five surgical scalpels. If a cat could grin, she was grinning. I heard a low growling purr from deep in her chest as she came around the desk toward me, eyes glinting.

My senses went into overdrive as adrenaline poured into my bloodstream. My arms were pinned behind me by the guards but I pushed myself to my feet so fast that they eased their grip on me slightly to grab my shoulders and force me down again. That easing was all I needed. I twisted violently enough almost to wrench my arms from their shoulder sockets, but the pain was nothing. I yanked one arm free, although the guard's claws raked bloody trails along its length.

I kicked the security officer in the chest, bowling her over backward against her desk while with my free fist I clubbed the guard still holding my arm. The other guard sank his claws into my shoulder, growling. I spun around and caught his chin with the heel of my hand, then drove a crippling blow to his windpipe. He sagged to the floor, gurgling blood, as I whirled to face the first guard, who was reaching for the pistol at his waist.

I grabbed his arm, twisted it so hard I felt bones snap, and shoved him into the security officer. She was still draped half across her desk. She pushed the howling guard away and pawed at her holster. I was much faster and snatched the gun out of her hand.

She glowered at me, blazing sheer hatred, as I held the pistol leveled at

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her face.

"I have told you the truth," I said. "I could kill you now but that would not change the truth of what I have spoken."

Another pair of guards bolted through the office door, saw that their commander was under my gun, and froze in their tracks.

"I won't willingly allow myself to be sliced up just because you want to find nonexistent traitors," I said to the officer. "I told you the truth. It was a total surprise to me that you have humans in this camp working with you."

I handed her the pistol. She grabbed it and started to swing it at me.

"And I bear a message from the Old Ones," I blurted.

She stopped in midswing. "The Old Ones? The creatures in the sea?"

"Yes," I said.

She hissed. But she put the gun down on the desk.

CHAPTER 13

They carried the injured guards away as the security officer fumed and snarled and slowly regained her self-control. At last she used the comm unit on her desk to speak to her superior, the base commandant. Within a few minutes I was brought to her office.

The bearded human, the one called Delos, was already there. The base commandant seemed older than the other Skorpis I had seen. The fur of her face and hands was graying. Her uniform was a pale blue, crusted with ribbons and decorations. The human scientist still wore gray shapeless coveralls.

"Is that all the uniform you have?" the base commander growled when they shoved me into her office.

"I've been swimming," I replied. "With the Old Ones."

Delos nearly jumped out of his chair. "The Old Ones? You've been with them?"

"I've spoken with them. They have a message for us."

The base commander waved the security officer out of the room. "I'll call if I need you," she said.

Once she had shut the door, the commandant got up from behind her desk and indicated the table on the other side of her spacious office.

"Sit there," she told me. Delos got up from his chair in front of the desk and joined us. The table was too high, the chair too big, for me to feel comfortable. It was like being a child at an adult's table. I felt small, almost humiliated.

Delos did not seem to mind the furniture at all.

"What did the Old Ones tell you?" he asked eagerly. "How did you make contact with them? Where are they from?"

"Will they join us in this war?" the base commander wanted to know.

"They refuse to join either side," I said. "They reject all attempts to draw them into the war."

"Reject, do they?" the base commander rumbled. "A nuclear bomb or two exploded at depth might change their opinion, I think."

"Your weapons will not work against them," I said. "That is what

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they told me."

"Nonsense!"

"I believe them. They are far older and wiser than we."

"So were the Tsihn, and we bashed them halfway across the Galaxy."

"And made eternal enemies of them," said Delos.

The commander's slitted eyes flashed, but she turned away from the scientist and said to me, "You must tell me everything that the Old Ones told you. I must know *precisely* what they said."

I repeated their message word for word, several times. The base commander sank deeper into a glowering unhappiness each time. The human scientist, though, seemed to grow more excited with each telling.

"Tens of millions of years older than humankind!" Delos said, almost smacking his lips with anticipation. "The things they can teach us! The things they must know!"

"They won't teach us anything as long as we continue killing one another. They regard us with loathing."

"But surely they would talk to scientists," Delos pleaded. "We're not fighters. We haven't killed anyone."

"Perhaps," I replied. "In time." I smiled inwardly, knowing that the Old Ones's contemplation of time was so far more leisurely than our own.

After repeating my story another half-dozen times, I was dismissed by the base commander. Outside her door, the security officer was waiting for me. If the Skorpis still had feline tails, hers would have been twitching with impatience.

"She believes you, does she?" she asked as she personally escorted me back to the prisoners' compound.

"How do you know that? Can you hear through a closed door?" The thought occurred to me that perhaps she had bugged her commander's office, under the guise of her security duties.

"No need to eavesdrop," she said grimly. "If the old tigress hadn't believed you, you would be chopped meat by now."

Before we were halfway to the prison compound, though, Delos came sprinting after us.

"The base commander's given me permission to house Orion in our quarters," he panted.

The security officer snorted, but we changed direction and went to the scientists' fenced-in area.

"He is your responsibility," she said ominously as she left me there with Delos.

He nodded and gestured toward the nearest of the low-roofed buildings.

"Wait," I said. Turning to the security officer, I asked, "What's going to happen to the rest of my troop?"

"The prisoners?" she made a movement with her shoulders that might have been a shrug. "Cryostorage, of course. We'll freeze them till we need them."

"Need them? For what?"

She bared her teeth. "For food, human. What else?"

"You eat humans?"

"They are made of meat, aren't they? Not as nutritious as some of the enemies we've fought, but they'll do

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in a pinch. With vitamin supplements, of course."

She seemed to be enjoying my consternation. I pulled myself together and said, "Well, until you put them in storage—or other arrangements are made for them—couldn't you find some shelter for them? And better rations?"

"No, I could not, human." And she turned abruptly and walked away from me.

The other scientists were just as eager to learn about the Old Ones as Delos was. They clustered around me once he had ushered me into their barracks. We were in a wide, bare room, furnished only with a long table and human-sized chairs and a pair of video machines off in one corner. A single row of windows on one side of the room looked out on the Skorpis camp, where purple twilight shadows were lengthening into night. The walls of the room were devoid of all decorations except for a single display screen showing an astronomical chart.

As I told my story still again I scanned the faces of the scientists around me. There were twenty-two of them, nine of them women. Most of them seemed young, the prime of their lives still ahead of them. Unlike my soldiers, they obviously were not cloned from one or two gene sets. They were tall and short, dark and fair, eyes of every shape and color, skin ranging from chocolate brown to pinkish white.

The woman called Randa, the one who had denounced me to the security officer, would not look directly at me. Either she felt ashamed of what she had done or she was angry at me for bringing danger to them. None of them commented on the claw wounds on my shoulder, matted with drying blood. I let it pass for the moment.

When I had finished my tale, though, I said, "Now I have some questions for you."

"Go ahead," said Delos. He was obviously the group's leader.

"What are you doing here on this planet, working for the Skorpis?"

"Working for the Skorpis?"

"What are you talking about?"

"We're not working for the Skorpis," said one of the men, with a considerable show of indignity. "They're working for us."

"The Skorpis are mercenary troops. They're here to guard us," said Delos, "while we try to study the Old Ones."

"Guard you against who?" I asked.

"Against you," Randa snapped. "And the rest of your homicidal maniacs who want to kill us all."

So it was anger that drove her, not shame.

"We had no idea there were other humans on this planet," I said. "All we were told was that there was a Skorpis base here and we were going to eliminate it."

"Typical military operation. They only tell you what they want you to know."

"Do you mean that humans are fighting against each other?" I asked. "We're involved in an interstellar civil war?"

"The Hegemony has been battling

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for its very existence for three generations now," said Randa. "Your so-called Commonwealth has been trying to annihilate us. You and your lizard allies."

"The Tsihn?"

"That's what they call themselves, yes," said one of the men.

"But how did the war start? What's it all about?"

"It started when Commonwealth fleets began attacking our settlements on a dozen different worlds."

"They wiped out whole biospheres. Killed everything."

"Burned planets right down to the bedrock."

"For no reason!"

"Without a declaration of war."

I shook my head. "It couldn't be for no reason. People don't attack one another for no reason."

"Lizards do."

"The Tsihn hate us. They hate all humans, anything that's not themselves."

"But you said that the Commonwealth is allied with the Tsihn."

"Against the Hegemony, that's right. But sooner or later the Tsihn will turn against the Commonwealth, too. You'll see."

There was real hatred in their voices, in their faces.

"I still don't understand how this could have begun," I said. "It doesn't make sense to me."

"You're just a soldier," Randa sneered. "How could you be expected to understand anything except killing people?"

That's what the Old Ones thought of me at first, I said to myself. But then they trusted me, they helped me.

Delos gave me a worried look. "Uh, if you really want to catch up on the history of the war, you can use one of our readers." He gestured to the video systems in the far corner of the room.

"Yes, why don't you do that?" said one of the other women. "We need to discuss how we can use your information, what our next steps will be."

I could see that they wanted to talk among themselves without me. And I was burning with curiosity to learn how and why this seemingly endless war had begun. So I went to the video reader and sat in the contoured chair before its screen.

"I'll show you how to run it." I looked up, surprised. It was Randa.

"I can operate it," I said. "Soldiers aren't complete idiots."

"Oh." Her face reddened. "All right." She turned on her heel and fled back to the others, who were sitting themselves around the long table.

I turned on the machine and softly spoke my request to its computer. The screen glowed briefly.

And instead of the history tape I wanted, Aten appeared standing before me where the machine had been. He wore a golden tunic and form-fitting tights with calf-length boots. And a frown. The golden aura of his presence enveloped me like a warm mist. I knew that he had brought me out of the continuum into a bubble of suspended spacetime where he could interrogate me fully while the men and women across the room neither saw nor heard us.

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"The Old Ones made contact with you, Orion."

I nodded solemnly.

"And they refuse to help us?"

"They refuse to become involved in our war in any way. Only after we stop the fighting will they even consider further contact with us."

"I had hoped for more."

"They were quite firm about it."

"There *must* be a way to convince them to help us! There must be."

"Perhaps you should try to contact them yourself," I suggested.

His frown deepened. "I have. We all have. The only one they responded to was you."

I must have smiled, "I'm flattered."

"Don't be," the Golden One snapped. "They saw you as a helpless victim of our cruelty. They took pity on you, Orion, nothing more."

"I disagree. When they first contacted me, in a dream I had, they were repelled. They saw only a warrior, a killer, a soldier who made war on other intelligent creatures. Later they saw that there is more to me than a killing machine. That's why they chose to speak to me."

"Remember, Orion, that *I* put those additional emotions into you."

"No you didn't. Not deliberately, at any rate. You built me to carry out your will, and for me to be able to do that I had to be able to think and act for myself. I've learned much about the world, Golden One. Much about the Creators and myself—and my fellow humans."

"Really?" Aten crossed his arms over his chest.

"Really. I'm more than your tool. I'm an individual. How many times have you berated me for not following your orders?"

"Stubbornness is not godliness, Orion. Only we Creators have full freedom of action. You obey me, whether you think so or not."

"You have full freedom of action?" I actually laughed at him. "Then why this desperate war? Why this need for help from the Old Ones?"

"That involves forces that your mind could never understand," he said. "I didn't build such capabilities into you."

"You didn't have to. I'm learning them on my own. The Old Ones speak to me and not to you. I am learning and growing."

"And some day you will challenge me," Aten mocked. "You sound like a frog planning vengeance on an elephant."

I decided it was foolish to carry on this vein. Changing the subject, I asked, "How did this war start? What is the reason for the fighting?"

"It was inevitable. As the human race expanded into the stars they met other intelligent species. Xenophobia is a basic emotion among all intelligences."

"Xenophobia doesn't start wars."

"Doesn't it?"

"Then how are the humans allied with the Tsihn? And how are the Skorpis working with. . . ." My words choked in my throat. Suddenly I understood what was happening.

Aten slowly unfolded his arms, studying me like a zoo keeper who had just added a new specimen to his collection.

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"This war—" I hesitated, thinking furiously. It was the only explanation I could see. "This war is really between you and the other Creators. You are fighting among yourselves, and using us as your pawns."

His utterly handsome face twisted into a smirk. "Of course. I'm surprised it took you so long to figure it out. You who prides himself on his growing wisdom."

"But why? Why would you have such a falling-out with the other Creators?"

"It's not only me, Orion. Our little family has split into two almost equal camps. Equal and opposite. Much as we did over Troy, except that this time, instead of a paltry few Greeks and Trojans, we are dealing with interstellar civilizations."

"And you drive them to war?"

He shrugged carelessly. "There was no other recourse. The other Creators would not listen to reason."

"They would say the same of you and your allies, wouldn't they?"

"I imagine so."

"You still haven't told me why you've split; the source of the conflict."

"We have reached the ultimate crisis, Orion. A dilemma so crucial, a turning point so critical to our survival, that we Creators could not agree on how to handle it. I told you that this war was part of the ultimate crisis, and so it is. Until I can force the other Creators to agree with my plan for handling the crisis, we will be powerless to face it when it finally falls upon us."

"So you're sending billions to slaughter, destroying whole planets, to decide how to deal with this final crisis."

"It is necessary. For our survival."

"You make war on each other by using us—and other races, as well."

"Why not? Do you expect us to fight each other, to kill one another?"

"And Anya? Whose side is she on?" But I knew the answer even as I asked the question.

Aten's face clouded over. "I'm afraid she is not among my allies. In fact, she is leading the opposition."

"Then, to serve you I must fight against her."

"It's her own fault, Orion."

I did not care whose fault it was or which of their sides was in the right, if either of them was. All I wanted was to find Anya, even if that meant working against Aten.

I looked into his gold-flecked eyes and saw that he understood precisely what was going through my mind. I could not hide my thoughts from him.

"The last thing in the world that you want to do is find her," he warned me. "She is far beyond the paltry romance that you once had with her. She has reverted to her true form, Athena, the warrior goddess. She no longer cares to don human shape. She no longer loves you."

"I don't believe you."

He made an indifferent gesture with his hands. "What you believe or fail to believe makes absolutely no difference."

"Doesn't it?"

"No, Orion, it doesn't. You can chase across the whole Galaxy seeking your beloved goddess. You can

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think me an egomaniac who sends his own creations to slaughter. No matter what you think, if you find Anya now she will kill you. Without a second thought."

"No! She loves me."

"Perhaps once she did. But she has outgrown you, outgrown the foolish desire to take on human form. She is truly the goddess of death, Orion. Your death. Believe it."

CHAPTER 14

For the next several days, as I worked with the human scientists, my mind kept spinning around the revelations that Aten had heaped upon me.

Anya was fighting against the Golden Ones. The Creators were split apart, and they had split the human race into two warring factions. They had even enlisted alien races in their ever-expanding war.

And Anya no longer loved me. That I refused to believe. She may hate Aten, she may be fighting against the Golden One with every quantum of her strength and knowledge, but she would never turn against me.

Yet I was a soldier in Aten's army. War washes sentiment away in torrents of blood. I could be killed as impersonally as a man swats an insect, light-years away from her, and she would never know it. I would be merely another casualty among the Creators's human pawns.

No! I could not accept it, could not believe it. Anya loves me, we have loved each other across the millennia and the light-years of space-time. She still loves me, just as I love her.

Could I find her? Could I reach her, wherever she is? Why must I fight this senseless war on Aten's side, instead of hers?

These were the thoughts that flooded my mind as I dutifully tried to help the human scientists at the Skorpis base on Lunga. In vain.

They had been sent to Lunga to establish contact with the Old Ones and enlist their aid in the interstellar war. The planet's only strategic value was that the Old Ones had a settlement here. My mission, at Aten's devious direction, had been to prevent the Hegemony from making an alliance with the Old Ones while he tried to establish contact with them himself.

My mission seemed oddly successful. The Old Ones refused to have any form of contact at all with the Hegemony scientists. We swam in the ocean for days and even had a full-sized submersible sent down to the Skorpis base. But no matter how far we went into that ocean, no matter how deep we dived, we saw no trace of the Old Ones.

"Maybe they've left the planet altogether," Delos suggested as he bent over the display screens in the cramped sensor center of the sub. Each of the screens showed an ocean teeming with sea life and no trace of the Old Ones.

"You say they had a city down here?" Randa asked me. In the confines of the sub's compartment we were practically pressing against one another. I could smell the faint trace of perfume in her hair. And a musky odor of perspiration.

Nodding, I replied, "A big city, al-

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though it really was more of a collection of lights than a set of structures."

"Well, there's no lights nor structures anywhere in view," Delos said with an exasperated sigh.

"Perhaps the sensors are being blocked in some way," I suggested. "Screened."

We sent out swimmers. I went out myself. Nothing. It was as if the Old Ones had never been there. Yet I got the distinct feeling that they were nearby, watching us, perhaps amused by our frustration.

The one good thing that I was able to accomplish during those discouraging days was to get better quarters for my troopers. I refused to be housed with the scientists, insisting that I was a soldier and I would share the treatment the other prisoners received. At the same time I pleaded with Delos and the Skorpis base commander, whenever I was brought to her presence, for a roof over the prisoners' compound.

One morning, just as I was about to be escorted to the scientists' buildings again, a Skorpis skimmer pulled up at the gate of the prison compound, loaded with sheets of plastic and bags of connectors.

"You will build yourselves a shelter," said the sergeants who drove the skimmer. "No tools are needed. Get to work."

By the time I returned that evening the shelter stood, neat and square. There was even bedding inside, I saw.

"Now we need partitions," Frede told me, quite seriously. "For privacy."

It astounded me how the troopers could adapt to their situation. They had slept on the bare ground and eaten one thin meal a day and been grateful that they were still alive.

"Now we need to escape," I said back to her. "Before they put us all in their larder."

Her eyes widened.

"To the Skorpis," I told her, "prisoners are food. The only reason we haven't been frozen so far is that the scientists want me to work with them and I told them that the price of my cooperation is to keep all of you alive."

"But as long as you work with the scientists. . . ."

I had to tell her, "I don't think it's going to be much longer. They're coming to the conclusion that there's nothing they can do to reach the Old Ones."

"Then we've got to get out of here pretty quickly."

"Yes," I agreed. "But how?"

That was a problem without a solution that I could find. There were forty-nine of us, unarmed, under constant watch, in the middle of a camp of at least a thousand Skorpis. I racked my brain for days on end trying to come up with a plan that might have some faint chance of working. Nothing.

Until one night it hit me. We don't need to escape. We need to be rescued.

I lay on the plastic floor of our prison, Frede next to me, staring up at the blank ceiling. I still had no clothes except for shorts I had been wearing for weeks. I closed my eyes and called silently to Aten.

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There was no answer. Nor had I expected one, at first. Summoning up my will and my memory I translated myself to the empty city of the Creators and stood once again beneath the warm sun on the hillside overlooking the city and the sea.

To those who can manipulate spacetime, it matters little if you are in a certain place for a moment or a millennium. You can always return to the place and the time where you started.

"I can wait," I called the cloud-flecked blue sky. "I can wait as long as you can."

I did not have to wait long. Almost immediately a silver glowing sphere appeared before me, so bright I could not look at it, yet I felt no heat from its brilliance. It coalesced, took the form of a man. The Creator whom I thought of as Hermes: dark haired, lean, the hint of mischief in his ebony eyes.

"Orion, the disturbance you make in the continuum is like a toothache."

"When did you ever experience a toothache?" I countered.

He grinned at me. "What is it? What brings you here all hot and impatient?"

"Are you part of this interstellar war?" I asked.

"Of course. We all are."

"And whose side are you on?"

His trickster's face took on a sly, cunning look. "Does it make a difference to you?"

"Can you take me to Anya?"

He thought a moment, then shook his head. "Better not to, Orion. She bears the weight of our future on her shoulders. She would not be glad to see either one of us."

"You serve the Golden One, then."

"I serve no one!" he blazed. "I have put in my lot on Aten's side, though, that is true."

"Then tell him that he must rescue my troop from the Skorpis base on Lunga."

"Tell him that he *must?* By your word?"

"If he expects me to serve him further," I said.

Hermes actually blinked at me. "You bargain with your Creator?"

I smiled back at him. "No, *you* bargain with him. I must return to my troopers."

And I opened my eyes in the prison shack at the Skorpis base, with Frede sleeping soundly beside me.

The rescue attempt, when it came, was just as fouled up as every other aspect of our mission to Lunga.

It was early afternoon. I was out in the submersible with nine of the other human scientists, including Delos—who went on every cruise—and Randa, who still seemed hostile and distant most of the time, although she could thaw slightly, especially when there was some interesting science to talk about.

The Skorpis warrior who accompanied us, so big that he could barely squeeze through the sub's hatches, filled the tiny comm compartment with his bulk. If humans felt uncomfortably dwarfed in Skorpis furniture, this warrior seemed ridiculous with a comm set clamped to his furry head. It was designed for human ears and

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human dimensions, but the warrior had managed to get the earphone to stay in his cuplike ear by slapping a strip of gummy tape across his head. It must have hurt when he pulled it off. I could see the pale scars of earlier tapes etched into his greenish fur.

"Return to base," he rumbled.

Delos, in the next compartment bent over the sensor displays, jerked his head up so suddenly he banged it on the metal overhead.

He yelped with pain, then said, "Return? Why?"

"Orders," answered the Skorpis.

Rubbing his head, Delos reached an arm into the comm compartment. "Please give me the other headset."

The Skorpis warrior complied and Delos held the set against his ear. Standing next to him, I could hear the communications operator on the other end.

"Enemy fleet has been observed approaching the planet. Return to base immediately."

The rescue mission, I thought. My heart began to race.

"But if there's a battle we'll be safer here in the sea, submerged, than at the base."

"Orders are to return to base. Immediately."

Delos wanted to argue, but the Skorpis at the comm console was already tapping his thick fingers on the keypads that activated the automated controls. We were returning to base, following orders.

And the Golden One was coming to rescue my troopers.

We broke to the surface a scant kilometer from the shore and cruised to the pier. As I clambered through the topside hatch and out onto the sub's deck, I could see no action. The sky looked clear and serene. But there was an air of electrical expectancy at the base that we could all feel as the human scientists who had remained ashore ran out onto the pier and helped tie up the sub.

We rushed back toward the scientists' compound, escorted by two fully armed warriors who had met us at the pier and the Skorpis who had run the comm console in the sub. His two comrades handed him a rifle and a flexible reflective vest as they ran.

"There's a shelter beneath the main building," Delos told me, panting with exertion. "The Skorpis insisted on building it even though I thought it was silly. Shielded and everything."

I saw that the base was buttoned up, braced for an attack. No one walking about, none of the usual drilling or workaday chores going on. Out by the perimeter the guns were manned. Automated laser batteries were already pointing skyward.

"I've got to see to my troopers," I said.

"Don't be foolish," Delos said. "Come with us where you'll be protected."

"I belong with my troop." I veered off, sprinting toward the prison shack.

No Skorpis tried to stop me, although Delos yelled, "Bring them to our shelter if you can."

I waved and ran faster toward the shack.

It was empty. Had the Skorpis already moved the prisoners to safety?

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I was surprised, doubtful.

Then I saw, to one side of the shack, a pile of canisters. "No!" I shouted. "They didn't!"

A high-pitched screeching shrilled through the air, the Skorpis equivalent of a siren, barely audible to a human. The attack was imminent.

No need to count the canisters. I knew what they were. Cryonic containers. The Skorpis had spent the morning freezing my troop. There was a big skimmer parked on the other side of the pile. They were going to move them to their food lockers when the attacking fleet was spotted.

I pounded the side of the flimsy shack hard enough to make it shake down to its plastic foundation. They're frozen! Frozen!

A heavy hand gripped my shoulder. Turning, I saw it was the security officer.

"Get to shelter," she commanded. "Attack is starting."

As she spoke a rash of laser blasts splashed against the energy dome shielding the base. The usually-invisible dome flared flame red for an instant, then orange. It cleared, but I could see it shimmering above us.

"To shelter," she hissed. "Now." She wrapped an arm around my waist, lifted me off my feet, and started running, carrying me like a sack of groceries.

More laser blasts splashed against the shield, and I heard the lightning cracks of the Skorpis lasers firing back. The whole world shuddered and we were knocked flat as a nuclear warhead hit the base of the shield. The shield absorbed most of the energy, but the kinetic pulse conducted by the ground was like the shock of an earthquake.

I scrambled to my feet; the security officer got to hers a bit more slowly. Through the shimmering shield I could see lights glinting in the sky, far overhead. Our ships, still in orbit, catching the light of the sun up there.

More nukes exploded and we staggered across the base, between buildings that swayed dangerously with each new explosion. The shield was flaming deeper and deeper into the red now, as more laser beams fired against it. It was only a matter of time until the shield was overloaded. Another blast knocked us to the ground again. Dust and grit filled the air, burning my eyes.

Spitting dirt from her begrimed face, the security officer pointed in the direction of the scientists' compound. "Shelter," she said. "You go there."

"What about you?"

"I have duty station." She hauled herself to her feet and started off in the opposite direction just as another nuke pounded outside the shield, making the shield go black for eons-long moments. The ground shook violently and several buildings collapsed. A heavy support beam cracked loose from one building and fell like an ax across the back of the security officer, flattening her beneath its weight.

I staggered over to her, through the choking dust, as more explosions shook the ground. The shield was visibly wobbling now, blinking red and

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orange and bubbling like water on the boil.

She was conscious, but barely. The beam had crushed her ribs, maybe broken her back. I strained against it, summoning up every reserve of strength in me, and hauled it off her. It fell to the ground beside us with a thunderous clunk.

I dared not turn her over. Her tunic was a mass of blood from her shoulders to her waist. She lay face-down, one cheek in the dirt, the other caked with grime.

One yellow eye gazed steadily at me. "You do not follow orders," she muttered.

"I'll get help."

"No one will come. I am dead. Go to shelter before you become dead too."

Her eye closed. She stopped breathing. I felt for a pulse in her throat, in her wrist. Nothing. She would have gleefully ripped me to ribbons a few days ago, yet I felt an enormous reluctance to leave her there, to admit that she was dead and there was nothing more that I could do.

Another blast and the twisted, crazily leaning side of the building next to us began to groan and shudder. I jumped to my feet and started running, glancing over my shoulder to see the whole building collapse in a thundering heap on top of the Skorpis's dead body.

For a moment I was disoriented. I stopped, blinking in the swirling dust while explosions thudded around me and the energy screen crackled and hissed like a badly-tuned video.

There! I recognized the scientists' compound. Its buildings still stood, although the electrical fence around it seemed to be turned off. The Skorpis must be feeding all the base's power into the energy shield, I thought. Once that shield is overloaded and shorts out, the attackers can blast the whole area with nukes.

But what good would that do? I asked myself as I dashed past the dead fence and into the largest building in the compound. The fleet's been sent here to rescue me and my troop, not annihilate us.

Or so I thought.

I had no idea of how to find their shelter. Must be a doorway or a hatch somewhere, but I could see none in the dim twilight caused by the dust sifting through the air outside. Another explosion shook the building so hard I nearly was knocked to my knees.

"Where's the shelter?" I bellowed as loudly as I could. "It's me, Orion!"

Almost immediately a section of the floor cracked open. "Down here," a voice shouted back. "Quick!"

I dashed for the trap door and yanked it wide enough to squeeze through just as a greenish light filled the room and I felt a dizzying, nauseating sense of vertigo that made my head swim.

Then everything went utterly blank.

CHAPTER 15

When I came to my senses once more I was hanging in midair almost three meters above the team of human scientists, who stood craning their necks upward toward me.

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I landed in their midst with a painful thump, knocking several of them to the metal plates of the flooring. I rolled over and sat up. Looking around, it was obvious that we were no longer in the Skorpis base.

"What happened?" asked one of the scientists.

"Where are we?"

"Transceiver beam," answered Delos. He was sitting beside me, rubbing the small of his back with both hands. He was one of the men I had bowled over when I fell.

"We're aboard one of the fleet vessels, then," I said.

"Looks that way, doesn't it?"

Indeed it did. We were in a metal chamber, bare except for a slit of an observation window set high in one wall and a tightly-closed hatch opposite it. I could feel the humming vibration of a star ship's engines through the deck plates.

Transceiver beam, I thought. The attacking fleet must have saturated the Skorpis defensive shield at last and then squirted the beam down to snatch us. The beam scanned our molecular patterns, annihilated us, then reproduced us here on the ship exactly as we were on the planet. That was why I materialized nearly three meters above the others; they had been in the shelter and I was at the lip of their trap door when the beam found us.

The transceiver beam had killed us, all of us, then rebuilt us here aboard the starship. No one willingly allows himself to be transported by a matter receiver.

But we were not asked.

"We're prisoners, then," said Randa.

"Maybe not," I said. "They may not understand who you are."

"Welcome to the *Blood Hunter,*" came a voice from above us. Looking up, I saw a red reptilian face glaring down at us from the observation window. This was a Tsihn ship, I realized.

I got to my feet and helped Delos and the others to theirs. The hatch swung open and a pair of reptilians entered the chamber, scaly green and lightly built, so alike I could not tell the difference between them.

"You will come with us," said one of them through the translator it carried on a thin chain around its neck.

The scientists were put into a fairly spacious compartment lined with bunks, like a barracks. I saw toilet facilities at the far end of the chamber.

"Which of you is the one called Orion?" asked one of the twins.

"I am," I answered.

"You will see the captain on the bridge." So I followed the green little reptilians—after they had carefully closed and locked the hatch to the scientists' barracks.

The bridge was compact and quiet. The reptilians do not make noise the way we mammalians do. I found it almost eerie the way every station was manned with reptiles of various size and hue, yet hardly a sound issued from any of them. There was no air of tension on the bridge. Only two of the lizards had their cyborg connectors plugged into the ship's sensors. The battle seemed to be finished.

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The Tsihn captain was almost my size. It sat in its command chair and looked me over the way a snake studies its prey. Its scales were mottled green and yellow with some gray spots here and there. Much of its upper torso was covered with insignias and markings of rank. Its snout was wide and filled with tiny needle-like teeth.

"You have no uniform?"

I realized I was still in my threadbare shorts. Before I could reply, it said, "We will provide you with a proper uniform."

"Thank you," I said.

It seemed decidedly unhappy. "I have lost many capable Tsihn to rescue you and the other humans."

"You arrived too late," I said. "The men and women of my assault team have been frozen by the Skorpis."

The reptile's tongue darted out from between those teeth, flicked back and forth for an instant, then retreated.

"So your team goes into the Skorpis's bellies."

"You can still pick them up, if you haven't destroyed their base altogether."

"Not destroyed," it said. "My orders were to locate you and bring you and the other humans to my ship. This I did. I bombarded the Skorpis base, overloaded their shield, and snatched you from them. It cost me a dozen Tsihn killed, many more wounded."

"But my troopers are still down there on the planet, frozen!"

"No concern. I have obeyed my orders. You are the one I was commanded to rescue. And those with you."

"But those are not my troops," I tried to make it understand. "My troops are still with the Skorpis."

"Yes, frozen, I know." The tongue flicked out again, then it asked, "So who are the humans with you?"

"Scientists," I said.

"I was told you would be with an assault team, not a pack of scientists."

I hesitated. If I revealed to the reptilian that these humans were enemies, what would he do?

It saw through my silence. "Scientists of the Hegemony, is that it?"

"They were studying the planet, trying to make contact with intelligent creatures in the sea. They are not soldiers," I said.

"But they served the enemy."

"The Skorpis were there to protect them."

The captain hissed in a way that almost sounded like laughter. "Some protectors! We snatched them right from between their claws!"

"But my troops are still there," I repeated. "They're the ones you were supposed to rescue. You must to go back—"

"Go back!" it snapped. "By now the Hegemony has a whole battle fleet swarming around Lunga. I have only four ships, two of them badly damaged by the Skorpis ground defenses. My mission was to sneak in and rescue you, not to take on a Hegemony battle fleet. We don't go back. We run away as fast as we can."

"But my troopers—"

"Can't be helped. Not now. This is war, human. Losses are to be expected."

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Not my troopers, I said to myself. Not Frede and Jerron and the rest of them. They've suffered enough. They've been through battle and done everything we asked of them. I'm not going to leave them to feed the Skorpis.

"Tell me about these scientists," the captain was saying to me. "They must have valuable information in their heads, no?"

"They're not military scientists," I said, warily. "They don't know anything about weapons or strategy."

"Still, they are a good prize to bring back to headquarters. A bonus. I will be praised."

"You'd be praised more if you brought back the troopers you were sent to rescue," I grumbled.

Its red eyes seemed to burn. "Orion, I was sent to rescue *you.* That I have done. My orders said to bring up any humans with you. That I have done, also."

I stood my ground and glowered back at it.

It shifted in its chair, then raised one taloned three-fingered hand. "Take the helm," it said to its second-in-command. Then it curled one of those taloned fingers and said, "Come with me, Orion."

Mutely I followed it through a hatch that we both had to duck through and into a small, dimly-lit compartment. I saw a wide bunk built into one bulkhead, a desk with a blank display screen above it. The captain's quarters, I guessed, spare and spartan.

"Sit," it commanded. There was only one chair, a stool, actually, in front of the desk. The captain eased its bulk onto the bed. It reached to a panel at the head of his bunk and a section of the bulkhead turned transparent.

I gasped. We were out in deep space, nothing to see but stars that were stretching into elongated streaks of light because of our ship's relativistic speed.

"We run with our tails between our legs, Orion," the captain said good-naturedly. "Soon we reach light-speed and then there is nothing out there to see."

I looked back at it and saw that it was holding a metal drinking cup out to me.

"Alcoholic beverages made from grain," it said. "I keep this for human guests."

"Thank you." I accepted the cup.

It reached into the compartment in its bunk again and poured something else into another cup. "Tsihn prefer drinks with blood in them."

We touched cups and drank. The liquor was smooth and warming.

"Many intelligent species have ritual of sharing food or drink to show friendship," said the captain. "I want you to know that even though I cannot rescue your assault team, I wish to be friendly with you."

"I understand," I said.

"War is never pretty. But maybe for your troops this is a better fate than they might have expected. They are frozen now. They feel nothing."

"But they must have known what the Skorpis intended when they were put into the freezer cells," I said. "Their last thoughts must have been hell."

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I realized that its darting tongue was the Tsihn equivalent of a sigh. "So what better did they have to look forward to? Your Commonwealth does not regard warriors with honor. The Hegemony, too. Humans treat their warriors very strangely, Orion."

"They treat them as if they're less than human," I admitted.

"Yes. Send them to do fighting, then freeze them when fighting's over." It shook its head. "Your warriors are treated like machines. Worse."

"I would still like to save them, if I could. I'd like to help them, find a place where they could live in peace and safety, without the Commonwealth forcing them to go into battle, without being frozen like some unwanted slabs of meat until they're needed again." I was thinking out loud now, letting my thoughts spin out to this stranger who was not human in form but more human than my own Creators in its sympathy.

"Put it out of your mind, Orion," said the captain. "I would like to retire to a planet I saw once, green and lush and so humid that steam rises from the swamps every morning of its year. But I will die in a metal egg. I will spend my life aboard this ship or another like it and one day, somewhere, I will be killed. That is the life of a warrior. That is what we are, Orion, you and I and all those others of so many different species. We were hatched to fight our peoples' battles. There is no other life for any of us."

I sat in that cramped compartment sipping at the whisky this reptilian captain had given me while we grew more morose and bitter. At last I pushed myself to my feet and asked it to excuse me. It ordered one of its bridge crew to show me to my quarters, which turned out to be a compartment almost identical to the captain's. The Tsihn showed me how to manipulate the controls to make the bulkhead transparent and to tap into the ship's communicator and computer systems. It slid back a panel and I saw a closet with two sets of uniforms hanging in it.

Once the reptilian left me alone, I slid the closet shut and stretched out on the bunk. It was a little short for me, but I did not care. I had no intention of sleeping in it.

I summoned the Golden One. I called across the currents of space-time to him. Speak to me, I urged. Give me a moment of your attention.

Nothing. He would not answer. I could have translated myself back to the Creators's city, but what good would that have done? Aten would not deign to see me there. The last time he had sent his messenger. I did not want a messenger, I wanted Aten himself, the Golden One.

But he would not reply to me. When I closed all my senses and tried to reach out to him with my mind and I received nothing but emptiness.

Wait! There was something. A tendril of thought. The faintest whisper of a contact.

Friend Orion, said the Old Ones. You have survived the battle.

But my troopers, I called to the Old Ones. They have been frozen. They will be killed.

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You want to save them.

I can't do it by myself. Can you help me?

We do not interfere in any way, Orion. We have made that pledge and we will keep it.

But my troopers. . . .

We feel your pain, Orion. You are gaining in wisdom. Pain is the price of wisdom.

Is there no way they can be saved?

That is for you to determine, friend. Use all your resources. Reach out to grasp the opportunities that surround you.

What opportunities? I asked.

But there was no further response. The Old Ones had said what they wanted to say and departed from my mind.

Use all your resources, they had told me. Grasp the opportunities that surround you.

I swung my legs off the bunk and reached across the narrow compartment to activate the ship's computer. Through the transparent bulkhead I could see that we were still flying at relativistic velocity, not yet beyond light-speed. I called up the tactical program and saw that there was indeed a full squadron of Hegemony battle cruisers chasing after us. The tactical plot showed that we would reach light-speed before they came within weapons' range. Once past light-speed we would be safe.

We would also be unable to send back a ship toward Lunga to pick up my troopers. Whatever I was going to do, I had to do it before we got to light-speed.

I had less than two hours to act.

* * *

CHAPTER 16

I spent nearly half that time at the computer screen, learning every aspect of the *Blood Hunter,* from engine rooms to weapons systems. I was particularly interested in the auxiliary ships that this cruiser carried. They ranged from tiny scouts to shuttles big enough to carry assault teams to a planet's surface.

I found that one might serve for what I had in mind: a survey ship that had an adequate carrying capacity and enough range and life support to make it all the way back to Lunga. If I could get it off the *Blood Hunter* before the warship reached light-speed.

I had to act quickly. I felt a momentary pang of regret that I would have to act against the captain who had tried to befriend me. But, as the reptilian itself had said, war is never pretty.

I had no weapons, but at least I had a decent uniform to wear: the blue of Earth's sky, with a high choker collar and a wide belt of gold. The buckle was a sunburst symbol, I saw. The emblem of the Golden One. I grimaced with distaste but cinched it around my waist, wishing I had a pistol to hang onto it.

Out into the passageway and straight down to the level where the Hegemony scientists were being kept. I passed several Tsihn of various sizes and hues; none of them tried to stop me or even acknowledged my presence in any way. Good. Let me be a non-person among them.

The hatch for the scientists' compartment was locked but unguarded.

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I simply unlocked it and ducked through. They seemed to be preparing for sleep; most of them were sitting on their bunks, a few huddled together in a corner of the chamber, talking.

"On your feet, all of you!" I snapped. "We're getting off this ship. *Now!*"

They dithered a bit, but once I told Delos that I was taking them back to Lunga he got them organized in quick order. Now came the hard part: getting all twenty-three of us down to the hangar bay where the survey vessel was docked.

"Stay close together and follow me," I told them. "If we're stopped, let me do the talking."

It almost worked.

We marched along the passageway and down the power ladder to the hangar level. A few Tsihn passed us, but none bothered to ask what we were doing. There were no guards posted inside the ship, but we found a quartet of mechanics working on a damaged scout ship in the repair bay down at the hangar level.

"Non-essential personnel are not allowed in this area," said the biggest of the mechanics.

"We're just passing through," I said.

It was not put off. "Security!" it called to the microphone built into the hangar bulkhead. "Unauthorized humans in the hangar bay!"

I smiled and said, "You've done your duty very well. The captain will be pleased with you."

And walked my gaggle of scientists past him, toward the pod where the survey vessel was housed.

It sat in the pod, a bulky ungainly conglomeration of spherical crew habitats, cargo holds, equipment containers and propulsion engines. It was a true spaceship, never meant to fly in an atmosphere or land on a planet's surface.

"Get your people aboard quickly," I said to Delos as I flipped open the cover of the pod's door controls.

"SECURITY TEAM TO HANGAR POD FOUR," bellowed the ship's intercom. "ON THE DOUBLE."

No time to study the door controls. The Tsihn would override the electronic system from the bridge, anyway. I just reached in and smashed the control panel with my fist. Then I grabbed the overhead door and pulled it shut manually. It moved grudgingly, but within a few seconds I had it closed and manually locked.

The airlock hatch was another matter. I sprinted into the survey ship and squeezed through its hatch.

"Seal the hatch once everyone's through," I said to the nearest scientist as I made my way forward to the cockpit. Delos was already in the pilot's seat, powering up the ship's systems. I slid into the other seat.

"You're going to get us all killed, you know," he said from between gritted teeth. But his fingers were flying across the control boards. Indicators were lighting up; I could hear the ship's generators whining to life.

"We've got to open the airlock hatch," I muttered, directing the computer screen to list an inventory of the ship's equipment.

"A ship like this doesn't carry

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weapons," Delos said.

But it did have a digging laser, I saw on the inventory list. A couple of touches of my fingertips and the computer showed me where the digger was stored.

I pushed out of the cockpit, commandeered two of the strongest-looking men, and went outside the ship to unpack the digging laser. Tsihn crewmen were pounding on the pod doors and the intercom blared:

"ORION, THIS IS THE CAPTAIN SPEAKING. HAVE YOU GONE INSANE? STOP THIS MADNESS AT ONCE OR I WILL BE FORCED TO ORDER MY WARRIORS TO BLAST THEIR WAY INTO THAT POD AND KILL ALL OF YOU!"

"Captain," I shouted, "I'm taking these humans back to Lunga to exchange them for my troopers."

"THAT IS IMPOSSIBLE. YOU HAVE NO ORDERS TO DO SO."

"I'm going to crash this ship through the airlock hatch," I bluffed.

"THAT WILL DAMAGE MY VESSEL AND KILL YOU."

"This survey vessel is built pretty solidly. I think I can make it through the airlock." I was working furiously as I spoke, helping the others to unpack the laser.

"MADNESS!"

"You could save a considerable amount of damage to your ship by opening the airlock," I said.

"THAT WOULD ALLOW YOU TO ESCAPE."

"That would save your ship from damage. Who knows, maybe this survey ship's engines will overheat and explode when I try to push her through the airlock hatches."

By now we had pulled the laser equipment free of its container and were starting to connect its power pack and alignment optics.

"YOU ARE THREATENING TO DESTROY MY SHIP!" the captain bellowed.

"I only want to get back to Lunga and barter these scientists for my troopers," I said.

"I COULD ALLOW YOU TO LEAVE THE *BLOOD HUNTER* AND THEN DESTROY YOU ONCE YOU ARE A SAFE DISTANCE AWAY."

I hadn't thought of that. "Yes, that's true. You could."

"Look!" shouted one of the scientists.

I followed his pointed finger and saw that the pod door was turning a dull red. The crewmen were working on it with a torch.

And then, with a rumble, the inner airlock hatch began to slide open.

"PUMPING DOWN TO VACUUM," said an automated computer voice. "THIS AREA SHOULD BE CLEARED OF ALL PERSONNEL IN TEN SECONDS."

We left the digger sitting in pieces on the deck and jammed through the ship's hatch. I pushed past the scientists crowding the main habitat sphere and went up to the cockpit. Randa was sitting alongside Delos.

"The captain's going to let us out," I said. Through the cockpit's observation port I saw that the outer airlock hatch was opening. I could see the stars out there.

"Yes, and then he'll blow us to eternity once we're clear of his precious

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ship," Randa muttered.

"I don't think so," I said, thinking of the captain who shared a drink with me.

The airlock was fully open now. Delos touched the propulsion master control key and the ship seemed to lurch once, then slide smoothly toward the open hatch, beyond it, and out into the dark starry void.

I leaned between them and punched at the communicator panel until the Tsihn captain's red-eyed face glared up from the screen at me.

"I'm sorry to betray you this way, Captain," I said. "But this is something that I must do."

It hissed. "I'm not even going to waste a shot on you, traitor. Let the Skorpis blow you to hell. There are plenty of them heading your way."

I grinned at it. "Thank you, Captain."

Its slitted eyes closed briefly, then it said, "Go with honor, Orion."

Minutes later the *Blood Hunter* winked out of sight with a soundless flash of blinding white light, safely in superlight velocity, beyond pursuit by the Skorpis.

Which we decidedly were not. As soon as Randa turned on the ship's long-range sensors, half a dozen battle cruisers showed on our tiny screen, heading our way.

Delos immediately began taping a message to be beamed to them. "This is Dr. Delos of the University of Farcall, chief of the scientific research team on the planet Lunga. We are returning to Lunga aboard a survey vessel. We are unarmed. Our entire compliment of crew is scientists and the human named Orion. I repeat, we are unarmed and are returning to Lunga."

Then we waited to see if the approaching Skorpis cruisers would listen to his message or shoot first and ask questions afterward.

They listened, and I could hear the sighs of relief echoing through the whole ship.

The commander of the Skorpis squadron spoke at length with Delos as the ponderous battle cruisers took up formation all around us. We headed back toward Lunga surrounded by the cruisers, a minnow being escorted by killer whales. It was almost ludicrous.

The scientists seemed tremendously relieved. Only as they gathered around me and thanked me for rescuing them from the Tsihn did I realize how much they had feared being prisoners.

"Those lizards make my blood run cold," said one of the women. "They don't have a shred of human decency."

I thought of the Skorpis and their eating habits and wondered how much political expediency shaped her attitudes. Your alien enemies are inhuman; your alien allies are extraterrestrials.

And beyond them all, beyond all the human factions and the alien intelligent races locked in this interstellar war were the Creators—descendants of the human race but evolved far beyond human form. Were there other far superior races involved, too? I wondered. Aten had spoken of the ultimate crisis as being something far

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more catastrophic than this "mere" war in which billions were being slaughtered and whole planets devastated.

I knew that the Old Ones existed, but they wished to play no part in the struggles that ensnared us. Might there be other races, far older, far superior to us? Was that the ultimate crisis Aten and the other Creators feared?

I had scant time to reflect on those matters. We were approaching Lunga again. Now I had to bargain for the lives of my troopers, which meant that the scientists who had just thanked me for saving them would soon be cursing me and trying to kill me. ■

TO BE CONTINUED IN THE NEXT ISSUE.

IN TIMES TO COME

Our July double issue offers an oversized feast of stories leading off with G. David Nordley's "Final Review," with cover by Jim Burns. It's another in Nordley's very popular series about Trimus, that uniquely grand experiment in cultural coexistence: humans, the flying Kleth, and the distantly whale-like Do'utians deliberately sharing a world with plenty of challenges for any one of them. The special things that happen when you put them together are even more challenging, like this case of mysterious death—which can only be solved by understanding that all the characters' actions are deeply rooted in their own very different evolutionary pasts.

Brian Stableford, well known from other publications, makes his *Analog* debut with another big novella, also with a strong element of mystery—but this one is a very different and thought-provoking kind of mystery, set in our own rather distant future. Charles Sheffield's fact article looks *much* farther out and ahead, to "The Long-Term Future of the Universe."

We'll also have Part 3 of Ben Bova's *Orion Among the Stars*, plus a wide variety of other stories by writers including Doug Larsen, Christopher Anvil, Jerry Oltion, Geoffrey A. Landis, and perhaps a promising newcomer or two.

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Becoming Human, Valerie J. Freireich, ROC, $4.99, 304 pp. (ISBN: 0-451-45396-4).
Archangel, Mike Conner, TOR, $21.95, 350 pp. (ISBN: 0-312-857343-8).
Northlight, Deborah Wheeler, DAW, $4.99, 352 pp. (ISBN: 0-88677-639-2).
Strange Attractors, Jeffrey A. Carver, TOR, $22.95, 384 pp. (ISBN: 0-312- 85641-5).
The Order War, L. E. Modesitt, Jr., TOR, 479 pp. (ISBN: 0-312-85569-9).
They Fly at Ciron, Samuel R. Delany, TOR, $19.95, 222 pp. (ISBN: 0-312-85775-6).

Valerie J. Freireich's **Becoming Human** is refreshingly unusual in its structure. Consider the character who initially carries the narrative: Alexander Greeneyes, a "toolman" genetically engineered to observe and analyze and to die young. His "owner," an Elector of the Polite Harmony of Worlds, does not regard him as human; he is an animal, a tool, good for no more than processing information for a society so dedicated to the proposition that information is a prime good that it spies on every public or semipublic move. On the other hand, she does go to bed with him.

Alexander's current task involves the Neulanders, a people so modified that they have no sense of pain, heal very quickly, and think torture parties (at which the participants slice, dice, and braise each other) are great fun. They wish membership in the Harmony, for only thus, they think, can they avoid the depredations of other worlds. Yet they are to Harmony eyes little more human than toolmen. There is strong opposition to their membership application.

Alexander can feel his early death approaching. The Neulanders offer help. He deals, but then his analytic skills alert him to the horror the Neulanders are planning to make their own plight seem more urgent to the Harmony. Obedient to his prime loyalties, he alerts his mistress and her colleagues. Then, his near-betrayal exposed, he is put down.

Now meet August, Alexander's clone. He is in the same Elector's service, fully aware of what his predecessor did, painfully aware that most of those around him view him as another Alexander, just as flawed, just as untrustworthy. He too feels the pain of feeling human and being

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treated as something less. And here are the Neulanders once more, penitent for past sins, still threatened by other neighbors, crying out for aid, and ultimately demonstrating that though being pain-free may make them willing to play some very hard-nosed games, it gives them no edge at all in sheer sadistic vengefulness.

This is a deeply poignant novel, a heartfelt consideration of one destiny to which the new technology of genetic engineering may bring us. Yet it is also cool, intellectual rather than passionate, at least by comparison to the rage and fury that have marked many literary reactions to racism. Perhaps this is why the characters are less than entirely convincing: We are accustomed to hearing a very sharp edge in the voices of those who have been denied full humanity. When it is lacking, the voices seem little more than echoes from a stage, though the words, the message, may be as poignant as anyone might wish.

It is worth stressing that Alexander's and August's situation is nothing new in the history of our species. Human beings have a deep-seated tendency to exclude anyone who is detectably different from the "Polite Harmony" of social discourse. To defeat this tendency, to be recognized as human, the excluded must find some way to be counted with the excluders. This is Freireich's point and theme, and the thrust of her plot, of which I would reveal too much if I were more specific.

Mike Conner, who won a Nebula Award for his story "Guide Dog," attacks the same basic problem with much more vigor in **Archangel**. His premise is that the flu epidemic of 1918 was promptly followed by the perhaps accidental release of a modified strain of the Ebola virus from a German biowar lab. Ebola is native to monkeys in Africa; when it gets into humans, it can kill promptly and nastily. The modified version, known as "Hun," is worse by far, for it interferes with the blood clotting mechanism so that victims bleed to death, virtually exploding all over their surroundings. Worse yet, Hun attacks whites, Asians, Amerindians, all racial stocks but the African, apparently because long exposure to the virus in Africa has led to a genetic resistance. Worse yet, Hun's causative agent cannot be stopped by quarantine, fire, bleach, anything. Its march across the face of the Earth is inexorable, and civilization as we know it—or as it was known in the 1920s, dominated by European-descended whites—is doomed. Cities and nations are depopulated except for the subhuman underclass. Tragedy unsurpassed from the white point of view. Chortle, chortle, rub our hands and grin all white teeth in black face, finally, finally, you got yours ofay, now it's our turn, yes, yes, yes, from the black point of view, and who can really blame them?

It's a setup, of course. Very imaginative, very clever, very pointed, and never mind that people don't bleed to death explosively, fire and bleach will too destroy even such a nasty virus, and *not* all African groups can be expected to have gained immunity,

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since Ebola is a pretty local thing. Leave Conner alone on those points. Give him a bit of rope and see what he does with it, for this situation is made to order to allow the white monster to show its fangs. After all, this is a blood disease, and when blood won't clot in the real world, one solution is to give transfusions of blood that *will* clot.

Oh-oh, you say? As soon as the white power-structure sees the nature of the situation, blacks will be herded into camps, force-bred to multiply their numbers, and bled white to keep the whites alive? That strikes me as a very likely response too, but Conner would have it that things fell apart very quickly in most areas, and the white power-structure was not that nasty. Indeed, he says, by 1930 there are only a few places where the old order manages to cling to its existence. One such city is Minneapolis, home to hardy stock, so determinedly fair-minded that as the whites die off the remainder invite blacks to come from the south and accept homes, training, and jobs to keep the system working.

Yet—Meet Danny Constantine, a second-rate newspaper photographer who, out one night to take art photos by a ruined flour mill, stumbles upon a strange murder. The victim was drained of blood. Soon there are other victims, and Danny's paper won't publish a word, even though Danny's camera captured images of the crime and a tall, gaunt onlooker.

Now meet Dr. Simon Gray, tall and gaunt, surgeon, chief of the Hematological Institute, party—along with the paper's publisher and numerous other local dignitaries—to a development scheme that will bring in many more blacks. What he is up to is not long a mystery, except in its details.

There are other characters, of course. Shirley, the young girl who lives in Danny's rooming house and has the mild form of Hun that won't kill her until her first menses. Bing, the newspaper columnist who knew Mencken and half-remembers Hemingway and drinks fishwise with Fitzgerald. The ball players struggling to hold teams and leagues together even if it means they must join forces with black teams. The title character, the Archangel, a disk jockey who spins old platters and dishes up a patter that is all there is to sustain some folks' morale. Danny interviewed her once and was smitten.

The Archangel will play a crucial part when Conner brings her to the fore. Until then, she and all the rest serve to bring the Minneapolis of this alternate 1930 to near-convincing life (did blacks really call whites "ofay" then?) and permit Conner to play an intriguing game of racism and justice.

The tale's greatest defect may be that Conner pulls his punches. As I noted above, I suspect this situation would bring out the worst in human nature as whites took full advantage of their power and of the beaten-in automatic subservience of blacks, just as Hitler did a decade later with the Jews. To say that it would not can be justified only for the sake of the story Conner wants to tell and the points he wants to make. Thus despite a great deal more rage and fury than

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Valerie Freireich showed in *Becoming Human*, Conner's tale is at heart as cool an exercise.

There is also a note of optimism at the end that—given the situation—rang quite false to me.

Even though I took a rather jaundiced view of Deborah Wheeler's *Jaydium*, I did say she showed an unusual emphasis on the quest for peace, deep cynicism about the impenetrability of folly, something of value shone through, and perhaps in some future novel she would unveil that something fully.

With **Northlight**, she goes a long way toward fulfilling that "perhaps." The setting is Harth, a world of Rangers and Guardians, civilized Laurea facing barbarian Northers, a priesthood that struggles to control technical innovation and environmental impact. There is a Starhall, and the reader immediately detects the smell of a colony world, perhaps a survivor of ecological disaster, deeply cautious about anything that might lead in the old direction.

Meet Kardith. She is a Ranger with a troubled past, stationed on the frontier to ward off the barbarians. Her lover Aviyya has disappeared over the border, and General Montborne had forbidden pursuit on pain of mutilation. But Aviyya's mother is Esmelda, a chief of Laureal City. Kardith has come to the city with despatches, hoping to persuade Esmelda to intervene—but she has arrived just in time to witness catastrophe, the assassination of Pateros, highest of Laurea's leaders, with a Norther dagger.

Yet the dagger proves to be a clever fraud, and when Esmelda's discontented son Terricel hies off with Kardith to find his sister, another one appears, aimed at him. There are plots afoot, danger in the air, and the clues point to Montborne, who hungers for bigger and better weapons of war.

The tale's central characters—Kardith and Terricel—are fairly well realized. Most of the rest are sketches, deft enough but often little more than postures. The plot moves briskly from crisis in Laureal to capture by the Norther barbarians to discovery of the true meaning of the Northlight of the title, with ample foreshadowing from the mysteriously spooky something in the air of the frontier. And the culmination quite satisfactorily evokes the sense of wonder.

Wheeler is developing nicely.

A year ago, I reviewed Jeffrey A. Carver's *Neptune Crossing*, the opening shot in a new series, *The Chaos Chronicles*. The protagonist, John Bandicut, was a spaceship pilot who had lost his ability to interface with computer nets and become a terrain surveyor on Triton. He discovered an alien gizmo, which planted an alien personality (the quarx) in his brain, told him of a disaster threatening Earth, and sent him off to collide with a comet. One might expect such an experience to leave very little of poor John—certainly John did—but when he opened his eyes he was facing a vast construct, an extragalactic space station, and he *knew* there was no way home.

The series' second shot is **Strange**

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Attractors. It begins with John Bandicut's entry into the space station with his two robot sidekicks, Napoleon and Copernicus, the discovery of mysteries, and a sudden dumping into a landscape whose mountainsides and rivers come alive with destructive intent. He is rescued by an alien being, Ik, who tells him there is a contamination in the control systems of the Metaworld or Metaship in which he is now ensconced. Ik is seeking his lost partner, Li-Jared, in a quest for information and a possible route home. Soon John, Ik, Li-Jared, the robots (now strangely upgraded), and the quarx are a team, and John too wants to go home, if only that were possible in the face of huge distances and what he thinks essential time dilations.

Soon the personal quest becomes a mission on behalf of whatever it is that controls the Metaworld and has brought this crew of strangers together: Find the contamination, the inimical, intelligent force that seems to have arisen from the sheer complexity of the Metaworld's own control systems (here is chaos theory once more, and something of those mathematical figures known as strange attractors), and defeat it.

Can they succeed? That much is inevitable, and the mission serves as a suitable excuse for a magical mystery tour of a small portion of the Metaworld, a glimpse of high-tech wonders galore, strange beings, and even a strange female who strikes John Bandicut as remarkably human (strange attraction!). The tale ends when, mission accomplished, the entire team is transferred to another venue, a world far away, deep in the home galaxy, where volume 3 will reveal a new mission, a new mystery tour, and perhaps even more signs that there may after all be a way for John Bandicut to return home—if he still so wishes.

The business of the lost way home reminds me of E. C. Tubb's Dumarest series, which Tubb kept going for many years and volumes. Is Carver planning something similar? If so, I rather expect he will do a better job of it, for he has a much better sense than Tubb ever managed of alien worlds and alien beings and far-future tech. For Tubb, all the worlds that Dumarest visited were really little more than repetitive, even monotonous stage-dressings. Carver is a much more original writer, and he manages much more in the way of sense of wonder.

On the other hand, Carver is not one for complex personalities or personal relationships. This makes his stories seem intended more for younger readers, and indeed when I was a teen I would have loved them all.

The magic of the Recluce of L. E. Modesitt, Jr., is of two sorts, order-based and chaos-based, and there is a balance such that the more order there is in the world, the more chaos there must be as well. One of the strongest forms of order is that of refined metal, especially iron, most especially when the iron is formed into machines such as steam engines.

So much was established in the earlier novels of Modesitt's Recluce series, *The Magic of Recluce*, *The*

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Towers of Sunset, and *The Magic Engineer*, which last I reviewed last August. In that one, the blacksmith Dorrin invented steam engines and successfully defeated the White Wizards of Fairhaven. Yet there remained the problem of the balance. Now, generations later, with Dorrin a figure of history, Recluce is strong, dominating the seas with steam. Yet the forces of chaos are also strong, stronger than ever, extending their sway over the continent of Candar, destroying all who oppose them, laying waste the nations.

The Order War begins by introducing Justen, another smith, good at his craft, adept at infusing order into his work, clever with both mind and hands. He is young and restless, and perhaps that is enough to explain what he does when Recluce's governing council (talked out of offering any real aid to the victims of chaos by a very conservative merchant) calls for volunteers to go help. Or perhaps it is the dream of a strange woman and a tree. Whatever, Justen feels obliged to go. So does his brother, the weather wizard. Between them they wreak utter havoc on the Whites, though not enough to stop the victory of chaos.

That victory leaves Justen separated by White forces from his side's remnants. He tries to find a way around, but the enemy spots him and pursues. He flees into the Stone Hills, dry and trackless, and there he is found by the woman of his dream.

She is a druid, a citizen of a land that fears neither chaos nor order, for it knows the balance. It also respects the balance, which means that it has a very hard-nosed attitude toward the laws of nature, and it is concerned that the Blacks and Whites, by their continual attempts to dominate the world with only chaos or only order will wind up destroying everything. "Justen," say Dayala and her people, "it is your mission to go home and set things right."

How he achieves this goal is interesting, for it relies on devising a way to blend chaos and order. At first, he thinks "false lead" is the key, but an older wizard steers him away from that, warning him of what is clearly—to a modern mind—radiation sickness. Instead, says the old fellow, use light, and then he toddles off chortling at the impossibility of the task he has set the youth.

But Justen is clever. Light is a chaotic thing, but with lenses and crystals and a bit of order, he discovers. . . . Well, what else but a sun-pumped laser? Add to that an armor-plated Stanley steamer, and the only remaining question is how many pieces the survivors will have to pick up later.

Modesitt is as clever as his blacksmith heroes, finding ways to discuss today's environmental concerns and technological hubris in ways that can reach a public that prefers wish-fulfillment fantasy to more hard-nosed SF or even—heaven forbid!—to technical education. Techie whizmoes are here as well, in terms of the natural forces (order and disorder) they embody, and the balance that is key to survival in the world. If people pay attention to what he is really say-

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ing—not just to the exciting, adventurous, gland-tweaking yarn he is spinning on the surface—there may be hope for our grandchildren.

Samuel R. Delany's **They Fly at Ciron** began its life as a short story first drafted in 1962 and published as a collaboration with Delany's friend James Sallis in 1971. Now it's a short novel with none of Sallis's contribution remaining except, says Delany, as a critique of his original intent.

Delany is a fine, expressive, thoughtful writer. He thus draws us quickly into his reflection on violence and love, conquest and rebellion, wisdom and heroism. He begins with the black-clad Myetrans, who are marching cross-country, conquering the villages they find by decimating the inhabitants whether they resist or no. Kire, a lieutenant of the brigade, has doubts about the need for such wanton slaughter; going off alone after a disagreement with his leader, Prince Nactor, he encounters Rahm, a native of the Myetrans's next target, Ciron. Rahm, returning from a wander, has paused to wrestle with a puma; even as he wins, impressing Kire, the latter uses his blaster to frighten away a Winged One, a member of a species of intelligent flyers feared by the Cironians. They are now friends, and Rahm gives Kire the lion's carcass.

This is of course not enough to induce the Myetrans to spare Ciron. They arrive and slaughter as usual. They imprison and enslave, and when a few individuals—notably the garbage collector Qualt and the wandering singer Naa—offer resistance, they react in predictable fashion.

Both Rahm and Qualt wind up befriending Winged Ones, who then come to Ciron's aid. Both are heroes, though Delany insists that the more violent of the two is less wise, less worthy of emulation and honor and even love.

Violence has its place, he says. It is useful, even necessary, and a society must retain the capacity for it if it is to survive. But once it has served its purpose, it should leave the stage.

He underlines this point with a pair of short stories, "Ruins," whose first version appeared in 1968, and "Return to Ciron," no prior publication indicated.

ANADEMS

Serendipity Systems (P. O. Box 140, San Simeon, CA 93452) is releasing my novel *Silicon Karma* (ISBN: 0-942871-5) on IBM-compatible disk for $9.95. It looks at the prospect of mind-transfer into computers from a more or less ecological standpoint, considering that life in the box will be constrained by the availability of such resources as memory and CPU time, thus making possible parasites and predators. This is a concept familiar to artificial-life researchers, but not to many writers who have chosen to present life in the box as something more like eternal wish-fulfillment.

Is it any good? Never ask the author. I can say, however, that one of the charms of writing the story was the way the effort to be more realistic led into quite bizarre territory. ■

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BRASS TACKS

Dear Dr. Schmidt:

"Sergeant Owen Rivers was not far away. . . . The Ford had experienced a massive structural failure . . . the leading edge, dragging on the road, had represented a braking force, and the car had spun around backwards" (Oct. '94, "The Missing Link" p. 94). The last part of this should have read "The leading edge, dragging on the road, had left the car very stable, but not at all controllable; firmly guided by the rear tires, it had tracked dead straight as the curved roadway drove out from under it."

Really, Dr. Schmidt! This is why rockets have tail fins!

We knew that! But it's fun to demonstrate it by wrapping foil around the front end of a toy car and setting it loose on a tilted drafting table. Nose first it dives. And it's the same even if the front wheels are just locked up with a rubber band; so it's *not* the high or low friction at the front that does it, it's the directional sensitivity at the rear, the "lift" per angle of attack. Same thing happens with the tail fins on a rocket, or any arrow, regardless of the drag of (say) a spherical nose or burning burlap.

I'm sure that Sergeant Rivers's dad, Inspector R W Rivers, developer of the RCMP's Traffic Accident Investigation programs (citations: C C Thomas, publisher, 1981-83), would never had made that mistake.

ALBERT G. FONDA, P.E.
King of Prussia, PA

The author replies. . . .

There is a small detail that Mr. Fonda seems to have overlooked. Later in the story Rivers is back at the crash site and finds:

". . . a tiny groove, less than the thickness of his fingernail, that cut diagonally across the pavement."

Thus, the body of the Ford, which we can safely assume to have been traveling straight down the highway, would have been cut diagonally as well. Even if you posit that a diagonally cut body would exert an equal amount of force across the width of the body of the car (an unreasonable assumption), the fact that the car was canted would have loaded the suspension differently on the two remaining wheels. This distortion of the normal suspension geometry would have caused the car to turn.

Another point is that the Door singularity, in cutting the front third off of the Ford, would have produced a lateral force on the car. Even a hot knife cutting through butter exerts some force on the stick of butter.

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I find Mr. Fonda's assertion that friction, i.e. drag, has no place in the analysis of the accident rather curious. In all the physics I'm familiar with, friction is regarded as a non-trivial element of any mechanical system. If the drag of a large enough piece of burning burlap is applied to an arrow, the directional stability afforded by the fletching will be overcome and it will swap ends—try it!

I dredged around and produced an old Corgi toy truck that tracked well and rolled smoothly. It came equipped with rubber tires, not the hard plastic that is common on toy vehicles these days; a more realistic model for a real car.

After locking the front wheels with a rubber band, as per Mr. Fonda's letter, I gave the truck a stout push. The truck tracked perfectly straight, leaving miniature skid marks on the hall floor. This held true whether the dragging wheels were in front or in back. The truck, however, would cover a notably longer distance with the rear wheels locked. This clearly indicates that the system is more stable with the drag in the back. A parachute, an admittedly extreme example of drag, is above the parachutist, trailing—not below, leading the way. (In the case of a vehicle, let's postulate a metastable state with the drag in the front, where it will track well as long as the entire system remains centered.)

However, if the truck was given even a slight twist to one side (to represent any or all of the above three lateral forces), the vehicle would slew violently as the dragging front end pulled it farther and farther around, and it would, indeed, swap ends. In the case of the Ford, after swapping ends and achieving a more stable state, the uneven drag across the cut end of the car and the loading of the suspension would cause the remains of the car to curve.

Thanks are in order for tracking the Rivers's family tree. Obviously, police work gets in some peoples' blood and stays there across generations.

GREY ROLLINS

Dear Mr. Stine:

I very much appreciated your article about "The British Colonial Shipping Board," in the October, 1994 issue of *Analog*. It hits very close to home.

First to the point of this note. I would very much like to see your references. Please send me a copy that I may learn more about the "British Colonial Shipping Board." I have enclosed the requested SASE.

I am one of those detail hounds who will, before reading much beyond an article's abstract, look at the author's references. Yes, I may have trod upon the same ground as the author, and may even know him or her, but there may be some reference or source I have not yet examined; there is always that possibility. New references are usually looked up. And there are many times that I will reexamine an old reference, especially if the author is reporting a conclusion different than one I may have reached reading the same material.

I am all too aware of the poor documentation by many authors. I also have the strange notion that shoddy

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citations, and writing, are symptoms, if not the actual disease, of poor research. Some I know are wrong because I have read them too, and others are so badly cited as to make it almost impossible to find. Some are probably fabrications, pure and simple; I know of several of these too. And, then, some are plagiarisms, and the issue must be with another author altogether.

I have one friend who likes to remind me of the little ditty: Once printed, must be right, twice printed, can't be wrong; thrice printed, gospel! Your example ought to be brought up again and again as a reminder to all of your readers that faith is best left to the clergy, but facts are in the worldly domain, and must be verifiable.

GARRIE L. TUFFORD

Willernie, MN

The author replies....

Dear Sir:

I'm glad you enjoyed my "Alternate View" column.

You asked for my references. I presume you meant those regarding the British Colonial Shipping Board. I did not mention in the column the individual from whom I heard this because I did not think it appropriate to connect his name with a questionable debating practice. However, other readers have found the source and attribute it to Jubal Harshaw in *Stranger In A Strange Land* by Robert A. Heinlein. So I am no longer reluctant to reveal the source for the reason I originally had.

I was first told about the British Colonial Shipping Board by Robert A. Heinlein in a private conversation in his home in Colorado Springs in 1951. He told me that he had used it during a debate at the United States Naval Academy while he was a midshipman there from 1925 until 1929. As with many authors, myself included, Heinlein used many incidents from his life in his writing.

I used this apocryphal debating incident merely as a hook on which to hang a column devoted to checking references before accepting them as gospel. No other purpose was intended. Besides, it did make a pretty good hook that grabbed the customer off the street and led him to read the column!

G. HARRY STINE

Dear Mr. Kingsbury:

Thanks for your input, but many of the claims in your *Analog* letter of Nov. 1994 are simply wrong:

(1) "The significant *fact* is that American and European populations are *not* declining because they are wealthy." This is untrue. The *total* fertility rate of (Catholic!) Italy is 1.3 (Ehrlich & Ehrlich, *The Population Explosion* (hereafter *TPE),* 1990, p. 196). That of most other western European countries is around 1.5 (*TPE,* p. 193). The replacement level is −2.1.

(2) Immigration is not a major contributor to popular growth in Europe because of the high political barriers the Europeans have erected. (In 1985 western Europe contained only 13 million immigrants; Paul Kennedy, *Preparing for the 21 Century,* p. 43). Indeed, immigration is a red herring.

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Your example of Kingsburys vs. Amerindians is irrelevant: Amerindians had both small numbers *and* a highly inferior level of military technology *vis à vis* the European invaders. This situation hardly obtains with Europe vs. those adjacent regions with the burgeoning populations. Historically, aggression by rising populations requires *superior* military technologies; see (e.g.) Paul Colinvaux, *The Fates of Nations,* 1980.

(3) You confound "wealth" with *things*—with "cities, roads and hamburger stands," or "natural capital." In fact the true source of wealth is *information:* whether embodied in people's heads as knowledge and skills, or (more subtly) embedded in a society's structure (e.g., its legal system, cultural attitudes toward entrepreneurs, etc.); or for a natural example, as embodied in (say) the organization of a seed that can produce an entire plant—and more seeds —from water, air, and sunlight.

In terms of physical goods, this means that value ultimately comes not from matter *per se* but from the *organization* of matter, as I've discussed at length in two *Analog* articles ("Beyond Prometheus," 12/93, and "The Environment, Technology Drivers, and Nanotechnology," 11/94). This point is also obviously implicit in Drexler's writings on nanotechnology. Such information-intensive technologies as small computers, fiber optics, and direct-broadcast satellite TV have far greater potential to raise Third World living standards than any number of new Las Vegases; and over the next couple of decades new developments such as cheap photovoltaics will have an even more staggering effect. As I point out, these technologies also are made of geochemically abundant elements.

Lest these "wonder technologies" seem irrelevant, Kennedy (op. cit.) points out that the industrial revolution was just beginning when Malthus wrote his famous *Essay,* and its major effects were still a generation off. We have no such excuse for not foreseeing the effects of new technology.

(4) You claim, ". . . that Mexico just has a longer way to go [to become wealthy]. It just isn't so." Um, references? In fact, this *assertion* just isn't so. Since "Salinastroika," Mexico *has* been doing much better—see (e.g.) *The Economist,* 13, Nov. 1993; also the Mexico review in the issue of Feb. 13, 1993. Now that Mexico appears to be putting its economic house in order, there is no reason they can't become the next South Korea. Mexico's problems have been social: it has been afflicted with statist economics and class polarization, which have throttled the Mexicans's potential productivity.

(5) Your assertion that even if Mexico pulls it off, "immigrants will pour into the country from poverty-stricken South American countries" is merely racist. If it's possible in Mexico, it's possible elsewhere. About a century ago Argentina (for example) had one of the highest standards of living in the world. They threw it away through an ill-advised turn toward statist economics back around the turn of the century; again, look (e.g.) at *The Economist*'s "Latin American survey" of Nov. 13 1993.

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(6) As for "biased" sample selection: You ignore the astonishing rise in living standards in east Asia, which was written off 30 years ago by the Ehrlichs and their like (e.g., go look at the first edition of *The Population Bomb)* Taiwan is even hitting the demographic transition (of which more below); see *The Economist* (June 5th-11th, 1993, p. 41).

(7) Historically it is just not true that "It is a stable population that generates wealth." Britain's population increased by about a factor of ~ 4 during the 19th century, but its wealth increased by a factor of 14 (e.g., Kennedy, op. cit., p. 8). To be sure, some of their population growth was siphoned off by emigration, but most were going to the US—whose wealth and population also increased, by an even more disproportionate ratio (see Kennedy's *Rise and Fall of the Great Powers)*! Similarly, the population of Germany increased from 49 to 66 million from 1890 to 1913 even as its economy burgeoned (*Rise and Fall of the Great Powers,* p. 210-211, and references therein).

The reason is simple: as the economists point out, every one of those new mouths to feed comes with a pair of hands attached, so as long as each new person produces more than s/he consumes, you're ahead. Way ahead, in fact, because the production grows exponentially faster than the population. People are the ultimate source of *production* as well as consumption, after all!

Of *course* this breaks down eventually, when people don't produce more than they consume. Nonetheless, a drop in birthrates occurs *after* a threshold level of wealth has been acquired. That's merely a matter of historical record, and it's called the "demographic transition." For a recent overview that also addresses many of the complications, see Gillis, Tilly, & Levine, eds., *The European Experience of Declining Fertility,* Blackwell, 1992. (Granted, it apparently takes more than *just* affluence to drop the birthrate, as these authors conclude. Besides rising expectations, evidently a demographic transition also comes about through a constellation of related social changes of which one of the most important is a change in the status of women. See, e.g., Ehrlich & Ehrlich, *Earth,* p. 211; *TPE,* p. 216; Kennedy, p. 341 ff. Nonetheless, affluence—or at least rising expectations—seems to be a necessary precondition.)

A *stable* population can "generate wealth" only when the contribution of human labor is overwhelmed by mechanized production, which presupposes a high level of technology.

(9) You undermine your own argument when you state "Sure nanotechnology and hydrogen fusion are going to save us." If it's possible at all it's possible now. Or is it just that those black and brown people won't be able to hack it, but the Europeans and Americans (and Japanese—"honorary Aryans," as Hitler said), tucked away in their "local hotspots," will?

In conclusion, polemics unbuttressed by references—that, indeed, disregard the references already given—merely generate heat. This is particularly true when the "facts" pre-

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sented are incorrect. Moreover, naive extrapolations of exp(ax) are merely misleading (as has been forcibly brought home to one who has worked in the resource business for the last 15 years!); the real world is not so simple.

STEPHEN L. GILLETT

Editors:

I was shocked to see that my response to Shawn Hurley's letter in the Mid-Dec '94 *Analog* was censored when you printed it. By cutting off the critical point at the end of the last paragraph, you made the call for people to contact their representatives in Washington sound like exactly the sort of hysteria I cautioned Shawn against in the opening of that letter.

Here's that paragraph as I wrote it: *If there is a theme to "The Last Plague" it's certainly not that we should shun those who have become infected by HIV, but quite the opposite. Those who really care about AIDS victims should be writing and calling their representatives in Washington every day, demanding that they support vigorous development of the space station. We need that laboratory in Earth orbit to find out what makes this thing tick so we can develop drugs to treat the victims and vaccines to prevent it from spreading further before it throws off a mutant strain we are unable to deal with."*

The point here is that there is a *solution* to the problem; we have the technology to properly investigate the virus. If we are going to spend billions of dollars of the taxpayers' money on AIDS, let's put that money into building the laboratory that can actually get us closer to a solution instead of running a disinformation campaign while we bury our heads in the sand and pretend it just isn't so.

GREGORY BENNETT

I'm sorry about any misconceptions this created, and appreciate the chance to set the record straight. However, I also feel obliged to set the record straight about what actually happened, which was not *censorship. The letter was originally set with the paragraph exactly as you wrote it, but when the column came back from the typesetter it was a few lines too long. So it was necessary to look for places where a few words could be dropped without significantly altering meaning, and unfortunately this was mistaken for one. This is probably a good time to remind letter writers that all magazines necessarily reserve to the right to edit for length and style, and most do it much more heavily than we do—but even here, things like this can happen.* ■

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UPCOMING EVENTS Anthony Lewis

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THYLACON (Australian National SF convention) at Wrest Point Hotel-Casino, Hobart, Tasmania. Guests of Honour: Kim Stanley Robinson, Peter Nicholls, Grant Stone. Registration: $A60 attending, $A20 supporting until 1 February, $A75 thereafter. Info: Thylacon, PO Box 397, Sandy Bay, Tasmania 7006, AUSTRALIA.

30 June-2 July

INCONJUNCTION XV (Indiana SF conference) at Adam's Mark Hotel, Indianapolis, Ind. Guest of Honor: Vonda N. McIntyre; Fan Guest: Missouri Smith & Florence Achenbach; Artist Guest of Honor: Randy Asplund-Faith; TM: Arlan Keith Andrews, Sr. Registration: $20 until 1 June, $25 thereafter and at the door. Info: InConJunction XV, Box 19776, Indianapolis IN 46219.

30 June-3 July

WESTERCON 48 (West Coast SF conference) at Red Lion/Jantzen Beach & Columbia River Hotels, Portland, Ore. Guest of Honor: Vernor Vinge; Artist Guest of Honor: John R. Foster; Fan Guest of Honor: Elayne Pelz. Info: Westercon 48, Box 2584, Portland OR 97208-2584. (503) 283-0802. CompuServe 74007, 3342 or GEnie JWestercon.48

24-28 August

INTERSECTION (52rd World Science Fiction Convention) at Scottish Exhibition & Conference Centre, Glasgow, Scotland. Guests of Honour: Samuel R. Delany & Gerry Anderson; Fan Guest of Honour: Vin¢ Clarke; TMs: Peter Morwood & Diane Duane. Registration: £80/US$125/CDN$160/DM210/DFI 240; Supporting: £15/US$25/CDN$30/DM40/DFI 45. At-door rates not set as of the time of this listing but will be greater than current attending rates. This is the SF universe's annual get-together. Professionals and readers from all over the world will be in attendance. Talks, panels, films, fancy dress competition—the works. Join now and get to nominate and vote for the Hugo Awards and the John W. Campbell Award for Best New Writer. Info: Intersection, AdMail 336, Glasgow G2 1BR, UK or intersection@smof.demon.co.uk ; Intersection, Box 15430, Washington DC 20003-4030, USA. (301) 345-5186 voice/fax

You can send me e-mail about your convention—A.LEWIS20 on the GEnie™ network. When calling conventions for information—do not call collect and do not call too late in the evening. ■

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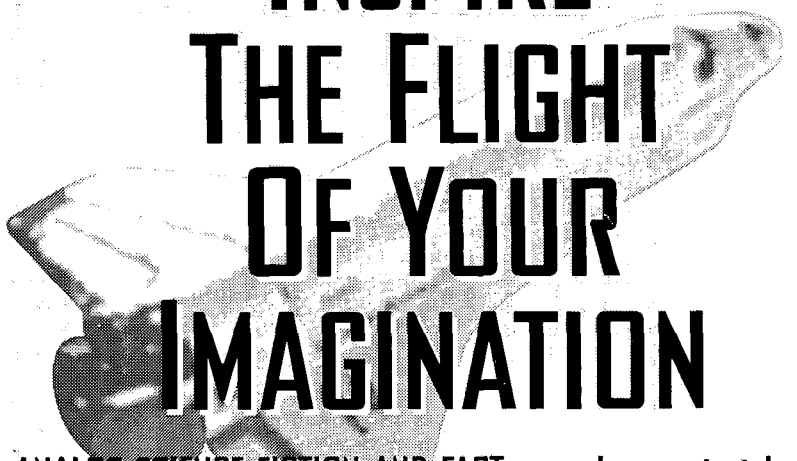

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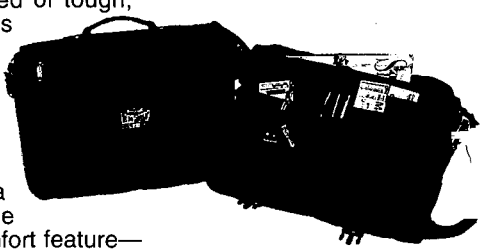

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